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GAS PRODUCER PUMPING PLANTS AT MANCHESTER, MASS.

BY RAYMOND C. ALLEN, ASSOCIATE MEMBER AMERICAN SOCIETY CIVIL ENGINEERS.

[*Read January 11, 1911.*]

The town of Manchester, or, as it is frequently called, Manchester-by-the-Sea, is a very pretty little town on the coast of Massachusetts Bay, between Beverly and Gloucester. It has a population of about 2 800, which is increased during three months by a large summer population to from 4 500 to 5 000. The summer estates are held in comparatively large tracts, and landscape gardening is carried to a high state of development, requiring as a result an abnormally large amount of water.

The original water supply in Manchester was derived from driven wells in the village, and was installed in 1891 and 1892 under the direction of Mr. Percy M. Blake, and was designed to supply about 200 000 gal. per day as a maximum.

With the installation of the plant the town entered upon a period of very substantial growth along summer-resort lines, and the need of more water soon made itself felt.

This need was met from time to time, over a period of some twelve years, by the driving of more wells, and the town was very fortunate, in that the watershed of its plant was able to yield up to about 500 000 gal. per day. During the last ten years, however, it became very evident that further sources of supply must be obtained if the needs of the community were to be properly met.

Many propositions were discussed and none found satisfactory, until in 1907 the entire matter was placed in the hands of Mr.

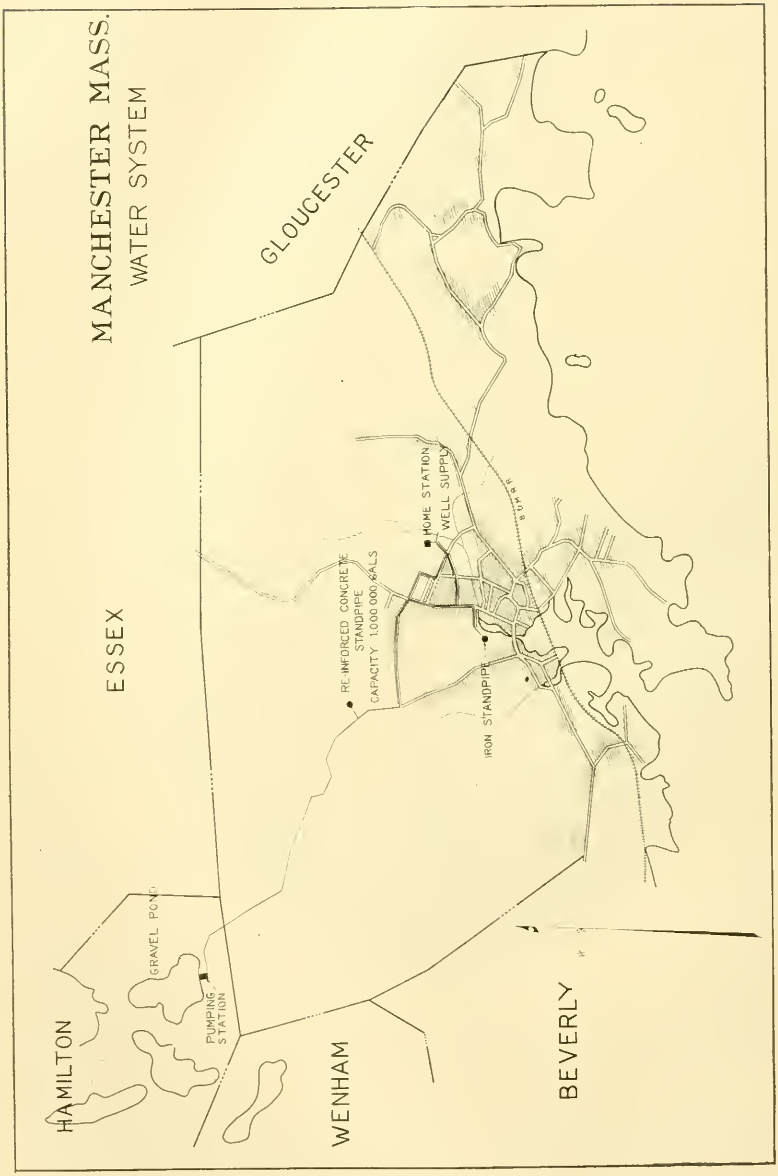

MANCHESTER MASS.
WATER SYSTEM
GLOUCESTER
ESSEX
HOME STATION
WELL SUPPLY
RE-INFORCED CONCRETE
STANDPIPE
CAPACITY 1,000,000 GALS
IRON STANDPIPE
B M R R
GRAVEL POND
PUMPING
STATION
HAMILTON
WENHAM
BEVERLY

Fig. 1.

Desmond FitzGerald, who, after a most painstaking and detailed study of the whole situation, recommended that the town secure the waters of Gravel and Round ponds, in the neighboring town of Hamilton, about three miles distant from the home pumping station.

This advice was adopted by the town and the supply obtained and developed. (Fig. 1.)

This development, of which the writer had charge, included the construction of about two miles of 14-in. and about one mile of 16-in. pipe line; the construction of a reinforced concrete reservoir 50 ft. in diameter and 72 ft. high, having a high-water line some 83 ft. higher than the old iron standpipe which failed to serve the higher hills of the town now in demand for building purposes, and the installation of new pumping machinery to raise the water to the new height.

The level of the high water in the new reservoir is 275 ft. above mean low water, that of the surface of Gravel Pond 50 ft.; and that of the floor of the home or old pumping station 22 ft. above the same level.

The total head, including friction for the Gravel Pond Station, amounts to 236 ft., and at the home station to 260 ft.

Owing to the fact that many years' experience had demonstrated that the flow of water from the driven wells at the home plant was limited to about 750 000 gal. in twenty-four hours, this was taken to be the size of the units to be installed there, and two one-million gallon units were decided upon for the Gravel Pond Plant.

At both stations it was decided to install units in duplicate.

The brake horse-power necessary per unit was determined to be 65 b.h.p. for the Gravel Pond Installation, and 50 b.h.p. for the home station.

Before obtaining bids, various pumping plants were studied to determine upon the method to be used. Steam pumps with from 90 000 000 to 100 000 000 ft.-lb. test duty were investigated; steam turbines direct connected to multistage centrifugal pumps; and oil and gasoline engines with power pumps, without satisfying ourselves that we had obtained that best suited to our needs.

The precedents and literature for the use of internal combustion

engines in pumping practice gave us but little upon which to base definite conclusions, and we were nearly ready to ask for bids on steam pumps when our attention was called to the use of producer gas.

Preliminary investigation interested us sufficiently to cause us to spend several weeks in travel and study of producer plants of about our horse-power in several of the eastern states. We visited such installations in numerous places and saw many and various types. The general efficiency obtained surprised us somewhat, and their reliability of operation did much to dispel many doubts in our minds. We saw these installations in factories where shut-downs meant expensive delay and financial loss, and found the owners generally pleased with the operation of their plants and that they were saving money over previous steam installations.

After careful investigation and study we determined to ask for proposals for suction gas producers, gas engines, and power pumps for the solution of our problem.

The next question arose as to whether we should ask for tenders for the complete plant, or whether we should ourselves determine the various component parts and install them. The first method had in its favor the element of undivided responsibility, and the guaranty of a specific duty for the complete plant; and had in its opposition the fact that we would have to pay a considerable sum for the superintendence and guaranty which, with the use of a little thought and study, we might save and spend to good advantage elsewhere.

The disadvantage of the second method was chiefly the matter of divided responsibility and the added detail study necessary for the engineer. Under this method we must also assume the responsibility of the efficiency of the combined plant, and see that each part of our equipment was of proper design and efficiency.

It was finally determined to adopt the latter method, and proposals were invited for two 50 h.p. and two 65 h.p. gas producers; two 50 b.h.p. and two 65 b.h.p. gas engines; two 750 000-gal. and two 1 000 000-gal. pumps. The specifications for this machinery were broad in their terms and stated the general problem to be solved. Producer makers were required to submit with their bids data as to the design and size of their equipment, especially in

relation to the grate area, scrubbing devices, and fuel efficiency guaranteed.

The engine bidders were required, among other items, to state their efficiency at varying loads, preferably in British thermal units per horse-power hour.

The following extract from the specifications will serve to explain the attitude taken by the writer: "It is the purpose of the Board of Water Commissioners to compare proposals upon the basis of cost plus the quality of design and workmanship of the apparatus proposed, and its fitness for the conditions of the town of Manchester, as judged by the said board."

Proposals were received from six manufacturers of gas producers, eight engine manufacturers, and four pump firms.

Two of the bids received for producers included engines in the price tendered. The others were as follows: $4 950; $6 965; $5 565; $5 720; and $5 000. The fuel to be used was pea and buckwheat-size anthracite, averaging about 12 500 B.t.u. The guaranties of efficiency ran from 75 per cent. to 80 per cent. of the heat of the coal in gas. The scrubbing arrangement in all but one type was that of coke or wooden slats and trays. The standover loss for a ten-hour run averaged about one pound coal per horse-power. The greatest difference was found in the grate areas, and the amount of coal to be gasified per square foot of grate surface. This some of the manufacturers claimed was entirely an arbitrary matter and of minor importance if the design of the producer was proper.

To the writer it seemed of the first importance and in deciding upon the producer to be used this factor was given important consideration by him. Data submitted showed some 50-h.p. producers with 3.7 and 4.9 sq. ft. area of grate and others of 7 sq. ft. for the same rating.

The smaller area means a greater amount of coal gasified per square foot of grate area with a hotter fire, more clinker, — the bane of the producer, — more frequent charging with consequent disturbance of the fire, and a more uneven gas.

The times to be charged during twenty-four hours varied from every three hours to ten hours.

The engine bids were all for four-cycle engines and varied from

single cylinder horizontal engines to four cylinder vertical types with weights running from 8 000 to 18 000 lb. for the 50 h.p. units.

Prices varied from $11 165 to $14 078 for two 50 h.p. and two 65 h.p., a total of 230 h.p.

The engine speed averaged very closely 270 r.p.m., all being very nearly that rate.

The fuel guarantees ran from 1.25 lb. of coal per h.p.-hr. to 10 000 effective B.t.u. per h.p.-hr. at full load.

Pump bids were on triple power pumps of both the double- and the single-acting types, and prices ranged from $6 115 to $9 590, with guarantees of from 78 per cent. to 85 per cent. efficiency.

The tabulation and study of the various bids and their many permutations and combinations gave the writer food for many hours' careful study and was indeed a difficult task. He was first concerned in selecting the units, which, from the data presented and from his observations, were best suited to the problem at hand. This after much balancing he determined only to find that he had selected nearly the most expensive combinations possible. Repeated attempts gave the same result and at length it was determined that of the proposals presented, those of the Smith Gas Power Company, of Lexington, Ohio, and that for the Nash Engine, by the National Meter Company, of New York, and that of the Goulds Manufacturing Company, of Seneca Falls, N. Y., were best suited to our needs, and the contracts were awarded to them.

The gas producers selected were of the kind termed Type B by the Smith Company. They operate on pea or buckwheat anthracite or on the semi-bituminous coals. The scrubbing device is a mechanical one occupying small space, situated on the gas line over the producer and consisting of two revolving enclosed baffle plates, belt driven, from the engine and running one within the other in opposite directions, at a speed of about 1 500 r.p.m. The gas passes upward through these plates and meets a spray of water in which it is literally washed and scrubbed, the impurities falling to a trap below and running thence to the drain.

This producer requires less room than the ordinary producer equipped with the tall tank scrubber of coke or wood and gives excellent results. The efficiency guaranteed was 75 per cent. to

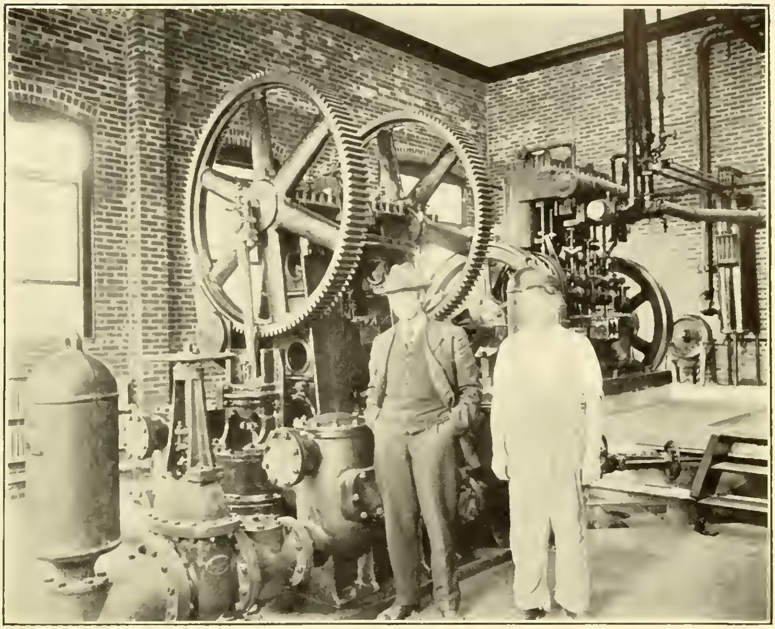


FIG. 1.

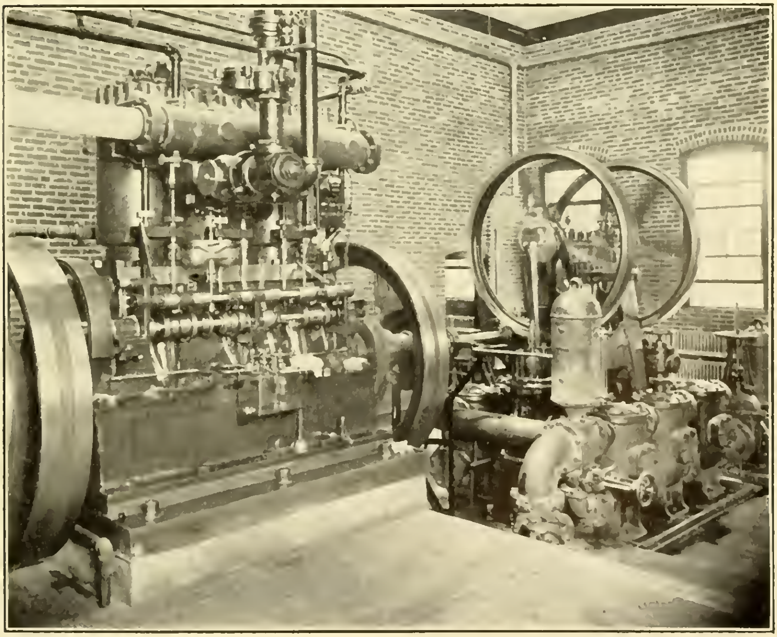
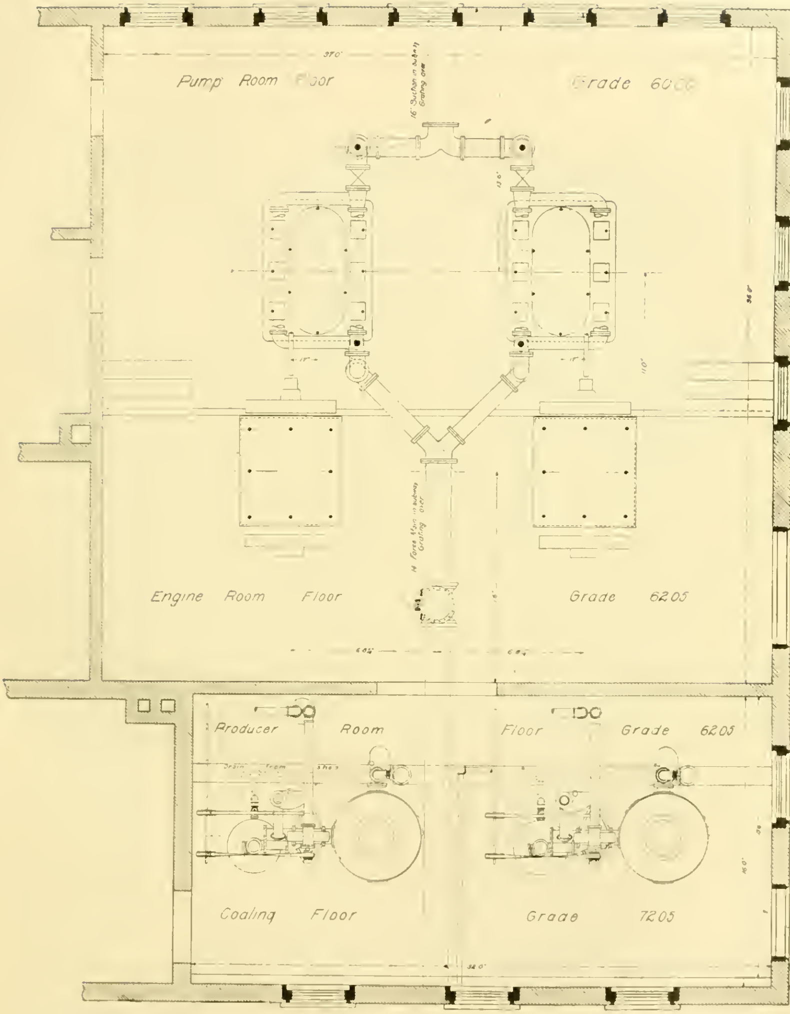


FIG. 2.
VIEWS OF ENGINE AND PUMP.



TOWN OF MANCHESTER
PUMPING STATION, GRAVEL POND
MACHINERY LAYOUT

FIG. 2.

80 per cent., and gas at the engine of 120 B.t.u. and 80 ft. per h.p. It is charged once in ten hours.

The Nash engines selected are of the three-cylinder type, the 50 h.p. having cylinders $9\frac{1}{2}$ in. by 11 in., and the 65 h.p. having cylinders $10\frac{1}{2}$ in. by 14 in. The compression for producer gas is about 160 lb. These engines were guaranteed to give their rated b.h.p. on 10 500 B.t.u. per h.p.-hr. at full load, 11 500 B.t.u. at three-fourths load, 13 500 B.t.u. at one-half load, and 23 000 B.t.u. at one-fourth load. Their speed is 260 r.p.m. for the 65 and 300 r.p.m. for the 50-h.p. engines.

The pumps are 8 in. by 10 in. and 9 in. by 12 in. double acting, for the 750 000-gal. and the 1 000 000-gal. respectively and are guaranteed as having an efficiency of 85 per cent.

A new brick station (Fig. 2) was designed by the writer at Gravel Pond for the two million-gallon units, and the machinery installed in the spring of 1909. The pipe lines and concrete standpipe having already been erected, the new plant was put in commission in June, 1909. About the first of August of the same year, the operatives having learned to operate the new plant, the home station was dismantled and the old steam pumps removed, and work was started upon the new equipment there. This was done at the height of our summer season, and that the faith we reposed in the new plant was not misplaced is evidenced by the fact that the entire season's work was carried through by this plant without any serious trouble whatever.

At the end of the succeeding November, the home plant was set in operation, and both have been in constant use since.

The operatives who run these plants are both old steam engineers and approached the work with some doubt and misgivings, having a large share of the feeling that while theoretically, perhaps, a horse-power is a horse-power, still that generated by steam is the most reliable. Their experience in learning the operation of the plants was without particular incident or difficulty, and as they became familiar with the new work and their interest increased, their efficiency kept pace with it, until they seem to have as much confidence in their plants as if their old friend steam was still working for them.

The producer consists essentially of an upright iron cylinder

FIG. 1.
VIEW OF PRODUCER AND SCRUBBER.

10 ft. high and 5 ft. in diameter, lined with suitable fire brick, into which coal is fed from the top. It is kept filled with coal for almost the entire depth, the space occupied by the bed of fire being quite thin.

The operator, commencing his work with the fire standing over, cleans his fire by means of poking bars which are passed vertically down from the top of the producer through small protected holes, close to the lining, working the fire ash to the grate. The fire is shaken by a swinging grate, and the ash and clinker removed from the lower doors.

Upon the skill of the operator in cleaning and coaling his fire rests in a great measure the best results as to economy and even running. It is not a difficult matter to learn, but its practice calls for constant and conscientious observance, if the best results are to be had.

The fire cleaned, the coal for the day's run is placed in the producers. This is fed from the top, and we have arranged our plants in such a manner that coal is stored at the level of the producer top and from thence wheeled directly to the producer.

The producer having been charged with coal, a pipe to the atmosphere is opened and a draft from below forced through the producer, starting up the fire, and in from five to fifteen minutes producing a gas whose quality is tested from time to time by lighting a burner attached to the line. When the flame burns at the right color for good gas the operator is ready to start his engine.

Shutting off his blower, which we run from a water motor, and closing the "standover pipe," the engine is started by turning it over by compressed air introduced into one cylinder. With the engine in motion from this agency, the other two cylinders draw in gas from the producer and commence their explosions. When these are occurring regularly the air is cut off from the other cylinder and gas admitted.

Current for ignition is furnished by storage batteries for starting and for regular running by a belt-driven magneto floating its excess on the storage cells.

The air for starting is compressed by an air-compressor belt-driven from a shaft operated from the engine. Another air com-

pressor is belt-connected with the water motor which is used to operate the power blower. This second air compressor and water motor we installed after being left without compressed air and both engines at rest.

The engines and producers are in duplicate and so arranged that either engine may be used with either producer.

With the engine running smoothly, the pump is put in by throwing in a friction clutch starting the pump with the by-pass open. The by-pass is slowly closed and the load is gradually picked up with the minimum of shock.

In shutting down it is the custom of our operatives to shut off the gas from the engine and let the whole plant come to rest gradually. By this means there is no perceptible water hammer; but if the clutch were to be pulled out suddenly, a very severe water hammer would result.

Pumping can be quietly and easily stopped and started at any time with the engine and pumps running by opening or closing the by-pass gradually.

The time necessary for starting from the fire left on the night before varies from thirty minutes to an hour in our experience, depending upon whether or not the operator has a helper in cleaning the fire. In an emergency the plant can be started without cleaning the fires, as soon as the blower can warm up the fire sufficiently to give good gas, or, under reasonably good conditions, in ten to fifteen minutes. From an empty producer I am not able to state how quickly the engine can be running, but we have accomplished it in about two and one-half hours.

The results of operation have been very satisfactory and fulfilled the guaranties given us for test conditions by the makers.

Test conditions have given us at the home plant, a pumping duty of 150 000 000 ft. lb. per 100 lb. of coal; or, allowing 85 per cent. efficiency for the pumps and a proper allowance for power for the scrubber, air pumps, etc., a consumption of 1.002 lb. of coal per h.p.-hr., including standover. At this plant we have a load of about 90 per cent. of our rating.

At the Gravel Pond Station, we have a load of but a trifle over three quarters of our rating, and a lower duty is naturally to be looked for.

Under test conditions at this plant under three-fourths load, we have obtained a pumping duty of 125 000 000; or, with the same allowance for efficiency of pump and shafting, a coal consumption of about 1.2 lb. of coal. Under a load of its rated capacity and a ten-hour run, the above results correspond to about 150 000 000 duty, and just about a pound of coal per b.h.p.-hr. for the engine and producer duty.

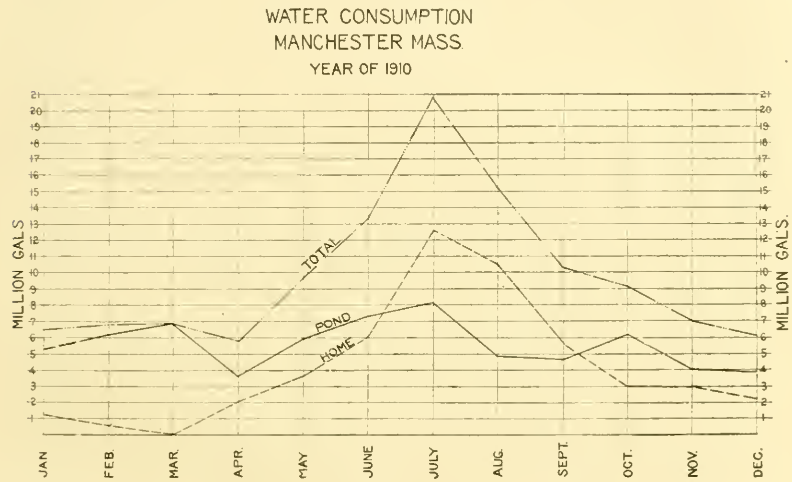


FIG. 3.

We draw our water from two sources and run both plants throughout the year mixing the water. (Fig. 3 shows the consumption for 1910.)

The home plant has its hardest work in the summer when the load is greatest and the cold ground water is desired, making long runs at nearly its full capacity.

The Gravel Pond Plant, on the other hand, runs more nearly uniformly, pumping about eight hours a day in the summer and five or six hours a day in the winter, and at two thirds its rating.

Under these conditions, the home plant gave for the summer months a pumping duty, including standover, from 104 000 000 to 135 000 000 ft. lb., averaging about 120 000 000 ft. lb. per 100 lb. of fuel.

During other months, when the plant is run but two or three days per week, and about five or six hours per day, and stands over the balance of the time, our duties including all standovers will average about 75 000 000 for a two-day run a week.

The results at the Gravel Pond Station, having due regard to the fact that the plant is run fewer hours per day and at a lower ratio to its capacity, are quite as good as those at the home station.

From January, 1910, to January 1, 1911, the home station pumped 50 880 000 gal. against a total head of 260 ft., at an expenditure of coal of 131 609 lb. This gives a duty of 83.3 million ft. lb. for the entire year.

At the Pond Station we have in the same time pumped 66 580,000 gal. at an expenditure of 175 479 lb. of coal or at a duty of 73.4 million ft. lb.

These figures, I would emphasize, are including all standovers and items of every sort, and include four to seven months when the plants are run but about six hours a day for but two or three days each week.

I would further emphasize the fact that, remembering what I have stated, that the economical running of a producer depends on the skill of the operator in handling his fire, the above duties represent the combined handling of several men during the year.

We are well satisfied with the result when we are able to pump some 118 000 000 gal. of water against a mean total head of 246 ft. with a total coal bill of $153\frac{1}{2}$ tons.

Our installations are for a total of 230 h.p. and cost us above the foundations, exclusive of pumps, $22 000, or a little less than $96 per b.h.p.

Including the pumps, the cost for the total equipment on foundation was about $32 000.

The experience of the department at Manchester is that all the operators who have run these two plants have learned their work readily and had no special difficulty in operating.

It has also shown, —

1. A cool, clean, uniform fire must be maintained in the producer, and, to obtain this, operators must learn from experience how to care for and maintain their fires and be persistent in so doing.

2. The operator must keep the engine clean and well oiled, and the ignition and compression in perfect order.

3. For the best economy the plants should be run at least ten hours per day, as a long standover and consequent cleaning and longer blowing up, use coal to no purpose.

4. That under the best conditions a station duty at full load of 150 000 000 ft. lb. per 100 lb. of coal can be obtained; and that a station duty for the summer months of 125 000 000 and for the year, including about six months when runs of but two or three days of six hours each are made, of about 80 000 000, can be obtained.

5. That our fuel cost with coal at $5 varies, for 1 000 000 gal. raised one foot, from an average of 1.73 cents in summer to 2.78 cents in the short runs and long standovers of winter; and, even when taken for the year and under the adverse conditions mentioned, the average for the year is 2.5 cents.

These are a few of the results which we have found at Manchester in the course of a year and a half of constant use, and we feel that they show good economy. The operation of the plant has not been at all difficult and the repairs very slight.

The writer feels that, for conditions of water-supply pumping similar to those at Manchester, the use of gas engines operating from suction producers is worthy of careful consideration, not particularly as to first cost, but to economy of operation. Were we at Manchester to install a new plant to-day, I am of the opinion that it would be of the type I have described to you.

DISCUSSION.

Mr. Frank L. Fuller.* I would like to ask Mr. Allen how nearly the Venturi meters agree with the pump displacement?

Mr. Allen. When the pumps were first installed they had a slip of about one per cent. At the present time it is a little less than two per cent. The pumps have not been packed since they were put in.

Mr. John C. Chase.† I would like to ask how near the service meters correspond with the meters on the suction?

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* Civil Engineer, Boston, Mass.

† Consulting Engineer, Derry Village, N. H.

Mr. Allen. I am working on that at the present time, but haven't any results to give yet. I am interested to see how it will come out.

Mr. Harry L. Thomas.* Mr. Allen is to be congratulated upon the fact that the operators have had so little trouble in managing the plant. We do not have any trouble now, but the paper which I presented two years ago † dealt particularly with the drawbacks in connection with such an installation. I might say that we have now conquered our difficulties and are entirely satisfied with the results that we are getting from our plant, so much so that we are in process of installing another plant, which will consist of a 2 million gallon pump with a 100 h.p. producer and an 85 h.p. gas engine. It is of a different make from our first plant, although of the suction type. We are getting, running as we now are, a duty of 90 million, and last October, when we were operating under conditions similar to those that obtained during the test of our plant in 1906, we developed 124 million. The duty during the test exceeded 140 million; I think it was between 140 and 142 million.

There are a few questions I would like to ask Mr. Allen. One is in regard to the exhaust pipe from the engine. At first we piped into a cast-iron muffler, and then from this muffler out through the roof of the building. Now we have run the pipe into a concrete pit, which is situated perhaps 90 feet from the building, and from that we lead a pipe into a dry well. We did this for the purpose of doing away with the noise of the exhaust, but we didn't provide for any expansion of the exhaust pipe, with the result that an elbow near the engine, at the free end of the pipe, simply went to pieces. I wonder just how Mr. Allen has provided for expansion, if he has similar conditions.

Another matter is about the chimney pipe from the generator, — whether it runs independently through the roof, or whether Mr. Allen considered running it into the chimney flue of the station.

Mr. Allen. In relation to the exhausts, we pipe them up through the roof and use no muffler. One of our plants is near the pond, in the wilderness, and it doesn't bother anybody. The

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* Assistant Superintendent, Hingham Water Company, Hingham, Mass.
† Journal N. E. W. W. A., Vol. XXII, p. 1.

other one is down in the village, but no one seems to notice it very much. We have three cylinder engines and they do not make nearly as much noise as the average automobile with the muffler cut out. The nearest house is about 100 yards away, and the neighborhood is thickly settled, but we don't hear any complaint about the noise. I think Mr. Thomas has a one cylinder engine and the exhaust comes at longer intervals, and so, perhaps, it makes more of an impression on anybody who is listening.

As to our standover pipes, I had intended to put them into the chimney, but after I had considered it and gotten advice I concluded I wouldn't, and piped them straight up through the roof. I think the straighter and freer one of these standover pipes can go, the better. I was also afraid that if I put them into the chimney I might get a collection of gas there, and some day somebody might come along with a stove and put the pipe in the chimney and we would have an explosion. I think it is a good idea to have the pipes go as directly to the air as possible.

Mr. Thomas. How about coal? What luck are you having in purchasing a uniform quality?

Mr. Allen. We are buying pea anthracite. I don't know just what the name of it is, but I am advised it has a thermal value of about 12 000 B.t.u. We are getting it for $5 a short ton delivered, and it runs pretty uniformly. We have had no trouble with sulphur, we have had very few back fires, and it gives quite a uniform gas. I am not familiar with the mine from which it comes, but it is the ordinary screening. We get it from a local dealer who screens his anthracite as it comes in. If we bought from the mines, we would have to buy in too large a quantity for our needs.

Mr. Thomas. At present we are using the Scranton Coal Company's pea coal. While we have had all sorts of difficulty in determining what was the best coal to use, and where to get it, we have finally settled upon this particular coal, which is giving us excellent results. We are pumping a million and a quarter gallons a day and burning from 1 050 to 1 080 pounds of coal. That is against 70 pounds pressure. We don't burn much less if we only pump against 40 pounds. There is greater economy in

pumping against a heavier pressure. Our coal is costing us, landed at the pumping station, $5.30 a long ton.

Mr. Hayes.* I should like to ask Mr. Allen whether the working platform around the generator is wood or iron.

Mr. Allen. Iron.

Mr. Fuller. I should like to ask Mr. Allen how much noise this plant makes in the building.

Mr. Allen. The 65 h.p. plant makes considerable noise in the building. The 50 h.p. plant makes a great deal less, whether because it is a smaller size or not I don't know. I think it is chiefly because there is a little more care taken in the timing gears. The pump gears have rawhide pinions and the noise from it is slight. The chief noise from the engine is from the cam shaft and the valve rods going up and down. One plant is quite noisy and the other quite comfortable, I should say.

* Of F. H. Hayes Machinery Company, Boston.

THE RELATION OF FLIES TO THE TRANSMISSION OF INFECTIOUS DISEASES.

BY HERBERT D. PEASE, SANITARY EXPERT, BOARD OF WATER SUPPLY, NEW YORK CITY.

[*Read September 22, 1910.*]

In the history of the development of sanitary science, as in the progress of all subjects where the natural sciences play a part, we find that the practical results have been those that have been sought for primarily. Thus, in the prevention of the spread of infectious diseases, those in which a method of transmission was discovered early have been the ones to which the greatest preventive efforts have been applied. In the case of typhoid fever, the early discovery of its relation to polluted water was the means of stimulating the development of the great engineering work which has made it possible to eliminate water-born typhoid.

We have come to a point where a large part of the value of the engineering aspects of this work have been demonstrated, and still we find what we are pleased to call "residual" typhoid fever. The cause of residual typhoid fever is a matter of the very greatest importance, not only to the sanitarian and to the epidemiologist, but also to those who are working in sanitary engineering, and even to those who are working in the special field of water purification. Because, if we are to get the greatest efficiency from the water purification works, we must decrease the amount of pollution having access to them, and that means that we must cut down the amount of typhoid fever caused by agencies other than by water.

If you have studied the occurrence of typhoid fever during the various seasons of the year in various parts of the world, you will find, in practically all civilized countries, that typhoid not only exists, but that there is what we call the "autumnal increase," or a special seasonal prevalence, of the disease. This has its height anywhere from July to October, varying in different parts of the world. This autumnal increase, in the opinion of many epidemiologists, has comparatively little to do with water transmission

of infection. For several years I have been looking for a first-class epidemic of typhoid fever in the late summer and early fall, which could be really fairly attributable to water transmission, and I may say that I know of none except those in which the pollution of the water has occurred almost immediately before its consumption. If the pollution has been a direct one, I think it is possible to have even typhoid bacilli carried by water in the summer time and in the early fall, but we have yet to find any outbreaks due to indirect water pollution in the summer season.

If we take, for example, the city of Albany, we will find that its maximum incidence of typhoid fever during the years when it was consuming raw Hudson River water occurred in the winter season, and yet the autumnal increase of the disease was also noted in the months of August, September, and October. Not long ago the filter plant of the city of Poughkeepsie was in bad condition. There was at about the same time a tremendous increase in the amount of typhoid fever in that city. This was in the winter season, but the autumnal increase in typhoid likewise existed. As soon as the filter plant in Albany was installed, the winter typhoid fever practically disappeared, but there was still the autumnal increase. In the city of Poughkeepsie the same thing was true. When the filtration system was put in good condition, the winter typhoid practically disappeared, but the autumnal increase was still present; and in the case of Poughkeepsie it was even greater than it had been before the filter was repaired and put in proper condition.

Now, what is the cause of the autumnal increase in typhoid fever? I do not really think any of us can satisfactorily answer that question. There are many factors to which have been attributed the cause in part, or in large part, — namely, milk, fresh vegetables, foods, shellfish, and contact cases. I think most medical epidemiologists believe that direct contact between cases, convalescents, and carrier cases, is the cause of a large part of the autumnal increase in the disease, especially in cities. The contact due to the migration from the cities to the country and back again in those months undoubtedly has something to do with it, but yet, unquestionably, flies play a considerable rôle in this increase.

Many epidemiologists believe that the flies are the means of

transmitting disease in the rural districts rather more than in the cities. Doubtless that is the case and that in the rural districts disease is much more frequently transmitted by the flies than in the cities. They argue that the opportunities for the fly to come in contact with infectious materials are not as great in the cities as in the country districts, and undoubtedly that is the case. D. D. Jackson, on the other hand, feels certain that flies are responsible for much of the summer typhoid and infant mortality in New York City, through the transmission of sewage bacteria from the water front. While some may doubt that the flies came in contact with the infectious material from the sewage left upon the pillars at the wharves and the piles and the wharves themselves by reason of the lowering of the tide, as was claimed by Jackson, there can be no doubt that the unsanitary conditions which exist around the piers in the city of New York, and in those very congested districts of the city near the piers, furnish ample opportunities for flies to become infected.

I shall speak a little later of the outbreaks of typhoid fever which have been caused by flies, and during which flies caught in the neighborhood of the cases where unsanitary conditions existed, were found to contain typhoid fever bacilli both on their legs and in their fecal discharges.

To speak more particularly about the fly, we will do well to note first that there are a great many varieties of flies, and undoubtedly many of them are of importance in this matter. It will not be possible to give a detailed description of the different types of flies, and why some of them are probably more important than others in the transmission of typhoid fever, but it will suffice to say that the fly which breeds upon organic matter of animal origin is probably much more important than the fly that breeds particularly upon decaying vegetable matter. Now, as a matter of fact, the ordinary house fly, the *Musca domestica*, which constitutes about 90 per cent. of the flies which are found in our houses and around habitations, does not breed in decaying animal matter. The female *domestica* lays its eggs chiefly in decaying vegetable matter, and apparently the only animal matter in which it will lay its eggs is human excrement. Some biologists even doubt that the *domestica* frequently lays its eggs in human excre-

ment. So the general statement the the *domestica* is responsible for most of the transmission of typhoid fever may be questioned by those who have observed that this species of fly does not lay its eggs frequently in animal matter.

There are, however, a large number of other flies, which, if we didn't stop to examine them, we would classify as the *domestica*, which are frequently present in civilized communities. There are the very small fruit flies which breed only in decaying fruit. Then there are the large flower flies which breed particularly among flowers and vegetation. Then we have, as you all know, the biting flies that develop in stables, and there are also the blue-green and so-called "blow" flies that develop particularly upon decaying animal matter. These flies are not seen frequently in human habitations.

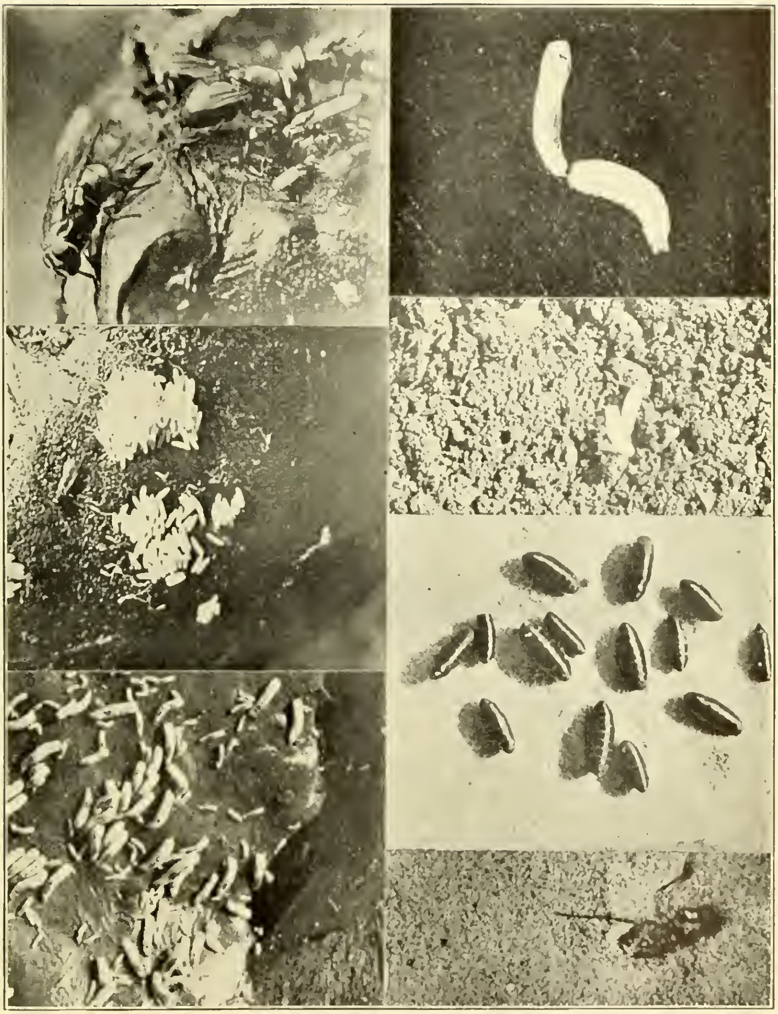
So we see that the species of fly and the method of breeding are matters of very considerable importance. The fly ordinarily lays its eggs in such a location as will furnish the best food for the development of the egg and for the nourishment of the larvæ. It is astonishing that so little is known about the course of development and life cycle of many of these species of flies other than the *domestica*. The *domestica* has been studied rather thoroughly, and most of the information which is to be had in literature concerns this particular species.

The female *domestica*, as I have said, lays its eggs in decaying vegetable matter and in human feces. It will lay at one time about fifty eggs, and these, depending upon the temperature, the amount of moisture present, and other physical conditions, will develop into the larval stage in from eight to twenty-four hours. The question of temperature is one of considerable importance in the matter of the life cycle of the *domestica*, and the question of moisture also determines its rate of growth.

The *domestica* will lay from one hundred and twenty to two hundred eggs in one season. Sometimes they pass through even as many as twelve generations in a season's cycle, all depending upon the temperature and the water and food supplies.

These eggs, fortunately for us, have a great many enemies. The various ants carry off a great many, as well as predatory flies of other species, for use as food. In many places the eggs and the

Plate I.
N. E. W. W. Association,
March, 1911.
Pease on
Flies and Infectious Diseases.



Photographs of Sections of Fly Pest Moving Picture Film.

Flies on a piece of meat.

Eggs of fly.

Larvæ hatched from eggs.

Larva molting.

Larvæ penetrating into earth to begin pupal existence.

Pupæ.

Wingless insect emerging from pupal stage in earth.

larvæ, or the maggots, as we commonly call them, are now grown artificially for the purpose of feeding high-grade and fancy fowl and birds.

The larval stage of the *domestica* is really its most important stage, from the standpoint of the growth of the fly, for it is during this stage that the fly reaches its full size. The fly, when it reaches the winged state, has already attained its full development. During the larval state, it molts, that is, it sheds its skin and grows to a larger size and again casts off its shell. This it will do twice during the course of the five days that it exists in this larval state.

During this stage it is possible to find large numbers of them in various decaying vegetable and excrementary material. They have been found as many as five hundred larvæ in one human excrement. The numbers that have been found in a pound of horse manure run up into the thousands. Various investigators have taken considerable pleasure in endeavoring to find a larger number than some other investigator.

From the larvæ stage, the fly passes into what is known as the pupal stage. During this period, the larvæ burrow into the earth, sometimes as far as five or six inches, and develop hard shells and there pass through another stage of their life cycle. At this time the insect is practically in a hibernating condition. This is a matter of considerable importance from the standpoint of the transmission of disease, for if typhoid feces should be thrown upon or buried in the soil, and were not put further down than six inches, it would be quite possible for fly larvæ to penetrate that distance into the soil, and take into their digestive tracts considerable amounts of this fecal material. When these larvæ developed into winged insects, they would discharge this same material and thereby distribute actual germs of diseases. If typhoid feces, for example, are placed in a dry earth closet where it is customary merely to cover the surface with a film of earth, it is quite possible for the larvæ to burrow under or into such material and become contaminated by actually eating the filth under the soil, and then coming out again in the state of the winged fly and transmitting the germs by means of their excrement.

Flies can hibernate in warm places during the winter time, not only in the pupal stage, but they can also do so in the form of the

winged insect itself; and one investigator, who seemed to be interested in the mathematics of the subject, found that in the spring forty thousand flies developed from twelve which had been hibernating in a warm place during the winter.

One of the most important phases of the relation of flies to the transmission of diseases is the question of the flight of the fly. But how far do flies usually go? When he does travel, he can make about ten miles an hour. Many say that flies never pass more than two hundred feet away from the place where they come out of the pupal stage into the winged state. But, as matter of fact, flies have been found many, many miles from the site of their full development. Some years ago I was familiar with a legal controversy between certain of the fish-oil companies and the Public Health and Marine-Hospital Service, over the location of a hospital near one of the company's factories. The testimony of the witnesses for the government went to prove that large numbers of the flies were found frequently far out at sea on steamboats and they were identified as coming from this region, where they bred and grew to maturity on the exposed drying fish refuse. It is therefore undoubtedly the case that flies can be blown, as mosquitoes can be blown, long distances. Ordinarily, the fly, probably, does not pass more than three hundred or four hundred feet away from the place where it originally developed into the winged insect; but that it can go a very much longer distance is undoubtedly true. In the latter case, the germs which they may take up into their digestive tract, and which they may carry in a virulent condition for periods of two to three weeks on the surface of the body, mixed in with the hairs and mucilaginous material which is on the pads of their feet, can be carried over long distances.

The fly not only breeds in decaying vegetable and animal matter, but it actually uses those materials as the source of its food. As I have already said, the larvæ take infectious matter into the digestive tract during that stage of their existence, and the winged insect will also do the same. Of course, as you know, the fly in feeding first liquefies the solid materials with its own secretions, and then absorbs the dissolved materials into its digestive tract.

The really important work in connection with the demonstration of flies as transmitters of disease was done in the early days of

bacteriology. In the Hamburg outbreak of Asiatic cholera, it was shown that flies were capable of taking the cholera bacteria into the digestive tract, and of giving them off in considerable numbers in the fly-specks or excrement, for periods up to two weeks. The living bacteria were also to be found on the surface of the fly during similar periods. Later on, this was shown to be the case with the typhoid bacillus, and we now know that the fly can take into its digestive tract living typhoid bacilli and continue to give them off for periods of from one to three weeks, and that the living typhoid bacillus can be found upon the legs and hairy body of the fly for somewhat similar periods.

One of the most interesting results of studies concerning the relation of flies to the transmission of disease has come from the work of Lord and others upon the association of the tubercle bacillus and the fly. Not only has it been shown that the fly harbors the tubercle bacillus as he does the typhoid bacillus, but it almost appears that there is an increase in the tubercle bacilli in the intestinal contents of the fly, when the fly has been fed upon tuberculous sputum. When we ponder over the fact that on the average one fly may deposit as many as fifty fly-specks during twenty-four hours, and that these fly-specks, when they are deposited upon food, may actually serve as a means for the introduction of living, virulent germs of disease into the human body, the importance of the fly problem becomes clearly evident. When the fly-specks are deposited upon substances such as furniture, wood, and cloth, they probably are without any significance from the sanitary standpoint, because the fly-speck naturally adheres to the surface of the material upon which it is laid and is not easily removed, and the effect of sunlight and air very soon kill off most of the varieties of the disease-producing organisms which it may contain. But where the fly has actually direct access to foods which are soon eaten without cooking, there is a direct means of introduction into the human system of the organisms which the fly has taken into its own digestive tract, or which it may have upon its legs and body.

It has been noted by Tooth and others that the fly seems to have a special predeliction for alighting on persons with typhoid fever. It is recorded by him that in the wards of a hospital flies

seemed to prefer to feed upon the skin and lips of the cases of typhoid rather than upon the cases of sunstroke and other diseases. Possibly this was due to the fact that the fly must of necessity have a certain amount of liquid diet in order to subsist, and in many rooms the only moist articles are the human beings, and naturally the flies are attracted by the perspiration of the people who are inhabiting these rooms.

One interesting item has been reported by Veniger. In the city of Vienna, there occurred a case of smallpox in a house not otherwise infected with this disease, but which was in close proximity to the smallpox hospital. A little child developed a localized smallpox infection upon the face. Those of you who are familiar with the clinical manifestations of smallpox know that it rarely occurs under natural conditions of infection except as a generalized disease. This child, however, had a localized smallpox infection on the face similar to the results of smallpox inoculation as formerly practiced, and the most plausible reason for the development of this localized smallpox seemed to be the possibility that a biting fly had come from the smallpox hospital, where it had fed upon the skin of the cases there and had introduced the virus into this spot on the face of this child..

Historically the fly is really of considerable interest. Those of you who care to do so can find many of the modern ideas on the transmission of disease and their prevention in the books of Leviticus and Deuteronomy in the Bible. Reading them in the light of modern knowledge, you will find very interesting revelations. I have no doubt that many of the customs of incense burning and fumigating in the Hebrew temples, and religious rites of that nature, were to a large extent hygienic measures. We know from a study of some of the other rites which were observed by the ancient Hebrews that their main practical object was the prevention of the spread of disease. For example, one of the interesting things which has been studied out is that the ancient Hebrews, as part of their religious offerings, burned those fatty parts of the cattle which were most likely to be infected with tuberculosis. It is undoubtedly true also that in many of the rites, such as the burnt-offering and the burning of incense, vapors were produced which would either kill or drive away flies. As you all know, the

temples where these rites were performed were practically the slaughter houses and the butcher shops of the Hebrew people, and it is inconceivable that flies of some sort were not pests under such conditions.

I will not go over all the ancient references to flies in connection with disease, but Sydenham, who was probably one of the greatest medical observers, said in 1666, "If flies are plentiful in summer, autumn is likely to be unhealthy."

The Bishop of Kund in the fifteenth century endeavored to foretell the outbreak of plague by the changes in the weather and the prevalence of flies.

Coming to the more practical application of the subject, it is certain that many of the cases of typhoid fever which have occurred in the modern wars have been due to flies. That much of the typhoid fever among the troops engaged in the Franco-Prussian War was due to flies is generally believed. It has certainly been demonstrated that in our own Spanish-American War a very large part, at least ninety per cent., of the typhoid fever was caused by fly transmission, and eighty per cent. of all the deaths from all causes were from typhoid fever. In the army camps, the germicides, such as lime, placed in the latrines and the sinks, for disinfecting purposes, were found upon the food in the camp kitchen in the form of fly-tracks. Then again, with the onset of cold weather, the amount of the disease diminished very greatly. In the Boer War, during which there were 6 000 cases of typhoid and only 7 500 killed in all the engagements, when the cold weather came on the typhoid rate decreased; and when also successful efforts were directed toward the suppression of the fly, the disease was likewise very greatly reduced.

I have already spoken of the work of D. D. Jackson for the Merchants Association of New York City, and I expressed the opinion that the incidence of typhoid fever near the water front in New York City was quite possibly attributable to the action of flies in transmitting infectious material from the unsanitary conditions in those neighborhoods, and possibly also to some extent from the transmission of organisms from the sewage-covered rocks and piles. Personally, I am confident that much of New York City's autumnal typhoid is due to the activity of flies.

One of the most definite outbreaks of typhoid fever attributable to flies was described by Dr. Alice Hamilton, and occurred in Chicago in 1902. It was found that certain regions inhabited by foreigners were showing a very considerable number of cases of typhoid fever. A sanitary survey of the location was made, and very unsanitary conditions were found. Open privies were common, and so were flies. Some of the latter were collected, and, out of 18 flies, 5 were found to contain typhoid bacilli both in their fecal discharges and upon the surface of their bodies. The distribution of the typhoid cases and all of the factors were in harmony with the conception that the outbreak was due to fly transmission.

Prof. E. O. Jordan, of the University of Chicago, showed very conclusively that the outbreak in Winnipeg, in 1904, of typhoid was due to fly transmission. There very unsanitary conditions existed, and the fly existed likewise in enormous numbers.

During my connection with the State Department of Health in Albany, I investigated an outbreak of typhoid fever in the village of Castleton, about eight miles below Albany on the Hudson River. A case of typhoid had existed in June on the second floor of a house near the river, below the main drainage line of the village. In so far as I could determine, the discharges in that case had been thrown out of the second story window into the adjoining yard. There were no water or sewerage systems in this village. The cases, about fifty or sixty in number, which had developed between June and September, all had their onset among people who had been living within a block and a half of that particular house. The patients belonged to all classes of society. Contact of a direct kind was out of the question as a cause of the outbreak. The cases were distributed among the customers of many milk dealers. In fact, all of the evidence pointed to the conclusion that this was a fly epidemic. No flies were caught and examined for typhoid bacilli, but doubtless the latter were there.

If the typhoid bacillus is transmitted by flies, undoubtedly many other organisms capable of producing certain diseases, like diarrheas, are likewise transmitted. In India especial attention has been paid to this aspect of the subject, and Arnsworth, Al-

dridge, and Snell, of the British Army, and a number of other men, have written exhaustive articles, accompanied by very elaborate charts, all showing the relation between flies and diarrheal diseases in that country. Dr. Jackson's work for New York City is quite conclusive on this point.

There are certain remedies for the fly pest which I will speak of very briefly. Of course, the first to suggest itself is to abolish the breeding places. To do so is a matter of general sanitation. Any decaying or decomposing vegetable or animal substance of any form, even decaying and molding newspapers, furnish good media for one or another species of fly in which to lay its eggs, and for the development of the larvæ. The employment of general sanitary measures proper for thickly settled communities, and even of country districts, will wipe out to a large extent the breeding places of many species of flies. But the manure piles are chiefly at fault, in so far as the ordinary house fly or the *domestica* is concerned. Removal of such accumulations to regions farther than three or four hundred feet from habitations is one of the most effective and probably the most practical method of eliminating these breeding places of flies. In many of our large cities where the horse is gradually disappearing flies are likewise gradually disappearing.

Where it is impossible to remove the manure as frequently as once in every five or six days, which is the time necessary for the fly to pass through its entire life cycle to winged insect stage, there are other means that may be taken; but they are very inefficient in comparison with the actual removal of the manure.

For example, the winged insect will not go into a dark place to lay its eggs; it hardly ever penetrates beyond a short distance away from the light; so that the screening and darkening of manure pits is a more or less satisfactory method of treating these places. The application of disinfectants to manure for the purpose of killing the larva has been a subject of considerable experimentation, and some few satisfactory results have been obtained; but likewise a great many not so satisfactory have been obtained. It should be said, therefore, that attempts to disinfect manure heaps and pits for the elimination of the fly eggs, larva, and pupa are not to be recommended if removal is possible.

After the flies are with us, we can endeavor to keep them away from our surroundings by means of screens and various methods of exclusion, or by catching them with the numerous kinds of sticky fly paper or with the newer mechanical devices. The most efficient of these have as the principle of their operation some well-known biological phenomena. Flies, as I have said, all seek the light, and if you darken all the windows by means of blinds and curtains, leaving one light, you will find most of the flies at that spot. Fly traps on windows and wire cages illuminated at night with phosphorescent paint or the use of poisoned fly foods and drinks and sticky sweets all have biological reasons for their popularity. It is astonishing what results have been obtained in the catching of flies by simple and yet thoroughly scientific devices.

OF WHAT THICKNESS SHALL WE MAKE THE WALLS OF OUR LARGE PIPE LINES?

BY ALLEN HAZEN, CIVIL ENGINEER.

[*Read November 9, 1910.*]

(1) Cast-iron pipe is commonly designed with an apparently much larger factor of safety than is used in the design of steel pipe. Notwithstanding this, cast-iron pipe frequently breaks in service, while steel pipe practically never breaks. Why is the steel pipe more reliable in this respect than cast-iron pipe?

(2) The president of a water board asked me, some years ago, after a very uncomfortable experience, how it was that pipes which had been tested in the foundry by a careful inspector, to a pressure of 300 lb., break in service under a working pressure of less than 100 lb.

(3) The formulas that we most commonly use in computing the strength of cast-iron pipe assume an ultimate tensile strength of only 16 000 to 18 000 lb. per square inch, with a factor of safety of 5, while it is well known that the castings turned out by pipe foundries at the present time considerably exceed this strength. Why is it not safe to reduce the thickness of the pipe walls in inverse ratio to the increased tensile strength of the iron?

These are questions which have come up for discussion in our office frequently in the last few years. In considering them I have frequently had the benefit of advice from Mr. Emil Kuichling, and I wish to acknowledge at once many of his suggestions in that which follows.

I propose to take up these questions to-day from the standpoint of all the forces that have to be actually met by the pipe in the trench and to see how thick the walls of the pipe really need to be to withstand these forces. In doing this I think we shall find at least a partial answer to these questions, and I hope that it may lead to discussion that will put the available knowledge on the subject in more satisfactory shape.

In this discussion I shall consider only pipes 36 in. in diameter and over. In smaller pipes the strength requisite to make the pipe act as a sufficiently stiff beam to resist breaking in the trench may be an element of considerable importance in determining the thickness of the walls. In larger pipes this may also be a matter of some importance, but I do not think that it will often control.

Let us consider first the forces that act upon the pipe and the stresses resulting therefrom, which have to be met and resisted.

(1) *Internal Pressure*. This may be divided into two parts: (*a*) the ordinary working pressure, and (*b*) the pressure resulting from water ram. The ordinary working pressure is ordinarily known with comparative certainty. The amount to be allowed for water ram is seldom known with anything like accuracy. In some cases, as, for instance, siphons opening freely to aqueducts or chambers at their ends, the conditions are not such as to permit any appreciable amount of water ram to occur, and the question is practically eliminated. The amount of water ram that may be obtained in long pipe lines is practically limited by the fact that the gates used upon the line ordinarily require a considerable time for them to be closed, and the longer they take in closing, the smaller is the probable amount of water ram that will result from the closing. Obviously, the use of gates smaller in diameter than the pipe line will allow them to be closed more quickly and will, therefore, tend to larger pressures from water ram.

Similarly, the operation of gates by hydraulic or electric power may permit them to be closed more rapidly with a great increase in the amount of water ram. It will, therefore, be desirable when such valves are used to so gear the electric motors, or provide such small openings to the hydraulic cylinders, that the operation of the gates will be very slow, corresponding in speed to hand operation. As it is only the final closing that produces water ram, it would seem mechanically possible to devise a gate that could be quickly brought by power to three fourths closed, and then move very slowly to its seat, by some change in the operating mechanism.

Mr. Kuichling has told me that in the 24-in. Rochester pipe line, with hand-operated gates of the same size as the pipe, with the most rapid closing of the gates that could be practically carried out, he never observed a water ram amounting to more than one

half of the static pressure behind the gate. Probably with proper precautions, on a long pipe line, the water ram may be held within these limits, but there may be exceptions.

For instance, at Springfield, in a short line of 42-in. steel pipe leading from the settling basin to the filters, a balanced valve was provided for automatically controlling the water level on the filters. Only a part of the water went through this valve. On one or more occasions the valve has stuck until the water level got some distance beyond what was intended, and then closing quickly, the water ram behind the valve has been so great as to force water through various riveted joints in quarter-inch steel plates in a connected water wheel casing. I should say in this case that, with a total static head of only about 25 ft., the water ram must, at the very least, have been over 100 lb. per square inch, or ten times the amount of head.

The conditions in this respect correspond to those in the ordinary hydraulic ram, which, as is well known, will lift water to a height more than ten times as great as the distance that the water falls.

It is a good rule to design all the gates on main pipe lines so as to prevent water ram as far as possible, and then allow fifty per cent. in addition to the static pressure.

(2) *Stresses from Internal Strains in the Metal.* In cast-iron pipe there are internal strains in the casting resulting from unequal cooling. Such strains may be assumed to always exist, but in amounts varying very greatly with the excellence of the procedure in cooling the pipe after casting.

In steel pipe there are also internal strains in the steel plates, but these are usually of much less practical significance than those existing in cast-iron pipe because the material is malleable instead of brittle and is capable of being bent and considerably distorted without reduction in strength.

(3) *Stresses that come from the Weight of the Backfill.* If the backfill pressed equally on the pipe from all directions, or, in other words, if it acted as a liquid, these pressures would be radial and balance each other. But such backfill is never obtained. The inequality in the distribution of pressures varies with different materials, and with the manner in which those materials are packed.

The best published discussion of this subject that the speaker has found is by Prof. Arthur N. Talbot, Bulletin of the University of Illinois, No. 22, April 29, 1908.

Professor Talbot concluded, as a result of his investigations, that for ordinary conditions it was best to assume that the pipe carries on its upper half a weight equal to the whole weight of the material in the backfill above the pipe as a uniformly distributed load, and that this weight is transmitted through the sides of the pipe to the supporting material underneath. The result of the weight of this backfill is to tend to break the pipe. For a condition of uniform loading and uniform support along the pipe underneath, Professor Talbot finds as a result of his experiments, in which many pipes were actually broken, that $M = \frac{WD}{16}$, where M is the moment of bending forces tending to break the pipe at that point in the pipe where it is greatest; W is the total weight of backfill above a unit length of pipe and D is the average diameter of the ring, which is practically the inside diameter plus the thickness.

For conditions of unequal loading and unequal support, the moment tending to break the pipe may be considerably greater than is computed by this formula.

(4) *Stresses due to the Beam Action of the Pipe.* We have considered thus far that the pipe was supported equally at every point along its bottom, and that the loading was equally distributed in the same way. As a matter of fact, this does not occur. The pipe is supported unequally along its length. With cast-iron pipe laid on blocking, and the blocking left in place, a considerable part of the pipe and its load after the trench is backfilled may still be carried on the blocks, and in this case the portion of pipe between the blocks acts as a beam, which must carry the weight of the pipe, the water in it, and the weight of the backfilling over it. If the trench is rock or has projecting bowlders, these may act in the same way and to an even greater extent, because the length of pipe between supports may be greater. Where a considerable length of pipe rests upon such projections on the bottom, there will obviously be a much greater tendency to break the pipe over these points because the forces acting upon a considerable length of pipe are concentrated on a small area.

(5) *Stresses Cumulative in Places.* The effect of internal water pressure is to produce circumferential tension through the whole section of the metal. The stresses due to unequal cooling of the castings are partly of compression and partly of tension, and may be both circumferential and longitudinal. The stresses due to the weight of the backfill are partly compression and partly tension, and are circumferential, when the pipe is uniformly loaded and supported. The stresses due to beam action are primarily longitudinal and, acting at 90 degrees from the others, do not need to be considered in connection with the circumferential strains. However, the effect of beam action is to increase the loading in places, and so increase considerably in those places the circumferential stresses due to the weight of the backfill.

For this purpose, limiting the discussion to pipes 36 in. in diameter and over, I shall consider at present only the circumferential stresses. These are cumulative in places. That is to say, there will be some points where the metal will be in tension from all of them,— from the internal pressure and from water ram, from the weight of the backfill, from the stresses due to unequal cooling of the metal, and also from the accumulated weight of the backfill caused by beam action.

When the accumulated stresses at any point exceed the ability of the metal to resist them, rupture begins and we have a broken pipe.

The formulas for the thickness of pipe in most general use take into account only the internal water pressure, including the ordinary working pressure and water ram. The other stresses are not taken into account.

These formulas have given reasonably satisfactory results for cast-iron pipe, because they have been based upon a working stress much below the stress that the metal is actually capable of sustaining, because the amount allowed for water ram has been in many cases above the truth, and because of an arbitrary addition to the computed thickness which adds considerably to the strength.

PROPOSED NEW METHOD OF COMPUTING THICKNESS OF CAST-IRON LIPE.

With Professor Talbot's work on the strength of pipes required to resist breaking in trenches, it seems possible to make a more rational calculation of the required thickness, based upon a higher unit working stress corresponding more nearly with the ultimate strength of the cast iron that is now available.

In carrying out this calculation no allowance is made at this time for internal stresses due to cooling, or for circumferential stresses resulting indirectly from beam action. It is assumed for the present that these and all other matters will be covered in the factor of safety, and that that factor will be increased if necessary to cover them in a subsequent revision of the calculation.

The calculation now made is to determine how thick the pipe must be to carry the stresses due to the backfilling as computed by Professor Talbot's formula, and at the same time to carry a stated internal pressure, with fifty per cent. addition thereto for water ram.

Let d = diameter in inches.

t = thickness in inches.

F = depth of backfill above top of pipe in feet.

s = permissible stress in pounds per square inch in cast-iron pipe, which I now take as 4 400 for an ultimate tensile strength of 22 000 lb., with a factor of safety of 5.

W = weight of fill over one linear inch of pipe at the rate of 115 lb. per cubic foot, the outside diameter of pipe being taken as 5 per cent. greater than d.

$$W = Fd\frac{1.05 \times 115}{144} = 0.84Fd.$$

M = breaking moment normally present from backfill, according to Talbot $= \frac{1}{16}WD$, D being the average diameter of the shell, which is about $1.025d$.

$$M = \frac{1}{16}1.025d(0.84Fd) = 0.0538Fd^2.$$

Resulting maximum circumferential stress in metal in lb. per sq. in. obtained by applying the usual formula, $M = \frac{1}{6}sbt^2$, b in this case being 1.

$$s_1 = \frac{6M}{t^2} = \frac{0.323Fd^2}{t^2}.$$

The stress available for resisting the water pressure is 4 400 less this amount. Of this, one third is allowed for water ram and two thirds for static pressure.

The stress allowable for resisting the static pressure is thus

$$s_2 = \frac{2}{3}\left(4\,400 - 0.322\frac{Fd^2}{t^2}\right).$$

H = head in feet that can be carried by a given stress:

$$s = \frac{r}{t} \text{ lb. pressure per sq. in.} = \frac{d}{2t} \times \frac{H}{2.31} \text{ and}$$

$$H = s\left(4.62\frac{t}{d}\right);$$

and for s_2 as reached above,

$$H = 3.08\frac{t}{d}\left(4400 - 0.322\frac{Fd^2}{t^2}\right) = 13\,500\frac{t}{d} - 0.99F\frac{t}{d}.$$

If we had taken the weight of the earth backfill as 116 lb. per cubic foot, the 0.99 would have been unity, and we may make it unity for the purpose of simplifying the formula. We shall then have —

$$H = 13\,500\frac{t}{d} - F\frac{d}{t}.$$

Our specifications allow a variation in the thickness of casting of 0.10 in. for large pipe. To insure that the stress shall not exceed the calculated amount at any point, if we could be sure that the specifications were literally complied with, it would only be necessary to add 0.10 in. to the computed thickness. This rule might be adopted for country work and where an occasional break in the pipe would not be of the greatest importance.

For city work, or where a break might do great damage, it would seem better to add 0.25 in. to the computed thickness, this being the allowance made in the Brackett formula in all cases for this purpose.

Solving the last equation for t, and making this addition, we have, —

For country work:

$$t = 0.10 + \frac{d}{27\,000}\left(H + \sqrt{54\,000F + H^2}\right).$$

For city work:

$$t = 0.25 + \frac{d}{27\ 000}\left(H + \sqrt{54\ 000F + H^2}\right).$$

This formula is not suggested as in any way final, but only for the purpose of discussion, and with the idea that it may possibly have in it some elements of a more rational calculation than are contained in the old formulas.

The formula for stress due to backfill is the one which Professor Talbot uses for ordinary backfilling of good material. With backfilling made of the very best material and with special care, the stress might be less. On the other hand, with poorly made backfill and with movements from settlement it might considerably exceed this figure. The most convenient way to allow for differences of this kind would be to allow more or less backfilling than the actual backfilling. For instance, with backfilling all made of coarse dry sand well tamped, it might be prudent to figure on a stress from backfill only three fourths as great as the actual backfill, while in rock trench with bowlders, or material that was sure to have subsequent settlements, the calculation might be made for a backfill fifty per cent. greater than the actual amount of backfill to be used, or even one hundred per cent. greater, if the conditions were very unfavorable.

For ordinary use it would seem fair to take 5 ft. of backfill in computing the thickness of pipe to be used in favorable trenches where the work was to be done with special care, and a larger amount up to 10 ft., or more, where the trench was deeper than usual and where there was rock or bowlders.

PIPE ACTUALLY BROKEN WITHOUT WATER PRESSURE.

In the first published paper of the American Society of Civil Engineers, Mr. Alfred W. Craven described some 72-in. pipe, $1\frac{3}{8}$ in. thick, laid in connection with the Croton Aqueduct, part of which was broken substantially without water pressure. The depth of backfill is not specifically stated in the paper, but from a statement of the load carried by the pipe I calculate that the approximate depth of backfill must have been about 10 ft. Taking the weight of the material from Mr. Craven's statement, the maxi-

mum stress resulting from this backfill was about 8 900 lb. per square inch. This, according to the statement, sufficed to break about 4 per cent. of the pipes.

In the *Engineering News*, December 15, 1904, Mr. Walter W. Patch describes 48-in. cast-iron pipe $1\frac{1}{4}$ in. thick under backfills ranging from 8 to 23 ft. He stated that in several places a number of adjoining pipes had developed longitudinal cracks in their entire length, etc. Using the formula as we have deduced it, the maximum stress in this pipe, with 23 ft. of backfill, would be 11 400 lb. per square inch.

Professor Talbot in his experiments tested pieces of 36-in. and 48-in. pipe from 1 in. to $1\frac{1}{2}$ in. thick carefully bedded in sand. Making the computation from the figures in his paper for the points where cracks first appeared, the stresses in 10 cases ranged from 15 000 to 41 000 lb. per square inch and averaged 25 000 lb.

In the two cases above mentioned, the inference may be drawn that, if the pipe was of full thickness and the iron of as good quality as may be reasonably assumed, the stresses that broke the pipe were about twice as great as those computed by the formula which is intended for uniform loading. In other words, the irregularities of the actual trench produced twice as much stress in certain places as was produced on an average by the careful loading in Professor Talbot's experiments.

A full reading of Professor Talbot's paper leaves little doubt of the actual doubling of these stresses at points in actual work, and at such points, with the calculation that I have just used, a factor of safety of only 2.5 will be left, certainly not too much to use for cast iron.

COMPARISON WITH BRACKETT FORMULA.

To see how the proposed new formula compares with the formulas in common use, I have taken the case of 42-in. pipe with 5 ft. of backfill. I have taken this because the question of the thickness and strength of 42-in. pipe has been under especial discussion in our office in the last year.

The results may be shown in tabular form.

Class of Pipe.	Standard Thickness in Inches.	Head in Feet Allowed by Brackett Formula.	Head Allowed by Formula now Reached. Country Work.	City Work.
A	0.87	50	Negative.	Negative.
B	1.00	100	57	Negative.
C	1.13	150	127	45
D	1.27	200	198	122
E	1.40	250	257	188
F	1.53	300	314	247

This indicates that according to the formula, Class A pipe is not really safe for 42-in. pipe with 5 ft. of backfill, even where there is no internal water pressure, and "B" pipe is not safe for city work. This corresponds with the practice of our office, where "C" pipe has been the thinnest pipe ordinarily used, and with the observation that has been made that 42-in. pipe 1 in. thick, even when cast and laid under the most favorable conditions, is not very reliable for moderate water pressures. For higher pressures the results correspond more nearly to those by the Brackett formula.

With pipe larger than 42 in. the differences, especially for moderate water pressures, would be greater and the formula proposed calls in general for considerably thicker pipe.

The practical effect of this study is to show that with large pipes the stresses resulting from the backfill upon the pipe are material, and are added to those resulting from the water pressure, and that when they are taken into account the factor of safety is by no means as great as has been assumed. It is largely and perhaps principally for this reason that cast-iron pipe which has stood successfully hydrostatic pressure in the foundry breaks in the trench with a fraction of the test pressure, and it is for this reason that it is not safe to reduce the thickness of the walls of pipes as rapidly as increase is made in the ultimate tensile strength of the castings.

AS TO STEEL PIPE.

In the case of steel pipe the conditions are somewhat different. The pipe may be backfilled to the point where the stresses due to the backfilling are above the elastic limit, and when this happens the pipe becomes permanently deformed. That is to say, the pipe is flattened and the vertical diameter is less than the horizontal diameter. This is a fairly common occurrence.

Cast-iron pipe is not permanently deformed in this way because it is comparatively brittle and incapable of yielding to any considerable extent. When the stresses become too great it is broken.

The best explanation of this is that the steel plate is malleable, while the cast iron is not. The steel plate comes to the shop flat. It is bent cold to the shape of the pipe. This process stresses the metal beyond its elastic limit, and produces a set. Nevertheless, the plate is just as strong after the process as before.

In the same way, the pressure of the backfill in the trench may deform the pipe considerably, stressing it beyond its elastic limit, and producing other sets; but these do not have the effect of weakening the pipe.

Cast-iron pipe, on the other hand, is not malleable. To bend it out of its original shape by even the fraction of an inch breaks and destroys it.

I think this is the main reason why steel pipes are not broken in water-works service.

Other secondary reasons are, that steel pipe is relatively cheap and that such liberal allowances have been made that the walls have been relatively thick and the stresses low, and that when excessive water ram occurs in riveted steel pipe the riveted joints open up slightly by a momentary stretching of the rivets, or yield in other parts, within their elastic limit, and allow water to escape from the joints. If the excess pressure is not too great and too long continued the pipe comes back at once to its original size, and is as tight as before. The effect of this is to make the riveted steel pipe act as a relief valve for itself and protect it from what otherwise might be the injurious effects of water ram.

Lock bar pipe, a form of steel pipe which has recently come into use, has stronger and tighter longitudinal joints and does not act in this way, except by the elasticity of the metal.

ALLOWANCE FOR CORROSION.

Steel pipe has frequently been made thicker than otherwise necessary, with the idea that it would still be thick enough for strength after it had been reduced in thickness to some extent by corrosion. Experience shows that the troublesome corrosion is

mainly pitting. Ordinary pitting does not greatly reduce the strength of the pipe. It is very rare that the corrosion is so widely extended over the surface of the plate as to reduce the strength of the pipe.

Mr. John R. Freeman has shown that a moderate amount of corrosion does not reduce the strength of riveted pipe at all, as the plate at the outset is much stronger than the joints, and corrosion of the joints to a reasonable extent does not reduce their strength. Of course, ultimately there would be rusting off of rivet heads, etc., but practically speaking, the corrosion of riveted pipe that actually takes place during a long term of years does not appreciably reduce its strength.

In the case of lock bar pipe, the original strength of the pipe is greater and represents nearly the full strength of the steel plates. Corrosion of lock bar pipe would sooner have the effect of reducing its strength, and there would be more reason for making an allowance for corrosion than in the case of riveted pipe.

VARIATION IN THICKNESS OF PLATES.

The plates in steel pipes probably vary in thickness by nearly as large a percentage as the variation in thickness of the walls of cast-iron pipe. There is this difference, however. The thickness of cast-iron pipe is given as the average thickness, while the thickness of steel pipe is given as the minimum thickness, and the process of manufacture by rolls insures obtaining it at every point. The actual thickness of steel pipes will usually overrun the stated thickness by amounts which may be as high as four to eight per cent., and which are greatest with thin plates.

INCREASING THE THICKNESS OF STEEL PIPE TO PREVENT PERFORATIONS.

The practical difficulty that has been experienced with steel pipe up to the present time is that of perforations by pittings. In other words, the pittings after a while go entirely through the plate and make leaks. The perforations that occur in this way are easily plugged, but if they are numerous it is troublesome to take

care of them. Very few steel pipe lines have reached this stage up to the present time. In a few cases there has been electrolysis from trolley currents, which has greatly aggravated this condition. This condition is one that must be kept in mind in considering steel pipe, and it may be considered worth while to increase the thickness of the plates in some cases with the idea of putting off the time when there will be perforations. It could hardly be expected that increasing the thickness of the plates would prevent the perforations; it would simply postpone the time when they would occur.

It is my feeling that it will not generally pay to increase the thickness of steel plates very greatly because of this consideration, but that the money will be better spent in better coating and in more careful inspection of the steel plates, or, in other words, by preventing the pitting instead of trying to make the plate thick enough so that the pitting will not go through it.

So far as deterioration may be anticipated from electrolysis from escaping electric currents, it is my feeling that it is better to spend the money on special protective measures, such as insulation joints and surrounding the pipe with insulating material where it is near trolley tracks, rather than in increasing the thickness of metal with the idea of making it thick enough to stand such deterioration without perforation.

Mr. Lochridge tells me that the steel pipe line at Springfield passing under two trolleys and parallel with one of them for a distance, and connecting with the general distribution system in the city, shows no electrical current, indicating complete efficiency of the insulating devices that were used.

PRACTICAL CONSIDERATIONS IN DETERMINING THE THICKNESS OF STEEL PIPE.

In the first place, the pipe must have a thickness sufficient to make it reasonably stiff in handling and in resisting the pressure of backfill in the trench. This means practically the use of $\frac{3}{16}$-in. plates in 36-in. pipe, $\frac{1}{4}$-in. plates in 48-in. pipe, $\frac{5}{16}$-in. plates in 60-in. pipe, and $\frac{3}{8}$-in. plates in 72-in. pipe. These may be taken as the minimum thicknesses below which it will very seldom pay to

go. In deep trench the plates must be thicker, or else the pipe must be surrounded with concrete, or otherwise stiffened. These minimum thicknesses may be used wherever they are strong enough to resist the internal pressure, and where they are not, additional thickness may be calculated so that the stresses in the metal from water pressure will not exceed the limits that are to be allowed.

The strength of the steel plates in pipes ranges from fifty to sixty-five thousand pounds per square inch. The elastic limit is not less than thirty thousand pounds per square inch. The safe working stress on the steel may be taken at fifteen thousand pounds per square inch. If the allowance for water ram is taken as equal to fifty per cent. of the static pressure the permissible stress for static pressure will be 10 000 lb. per square inch.

If lock bar pipe is used, and the strength of the joint as a minimum is taken as ninety per cent. of the strength of the plate, we may use a working stress of 9 000 lb. per square inch.

If double riveted pipe is used, with a strength of joint assumed to be seventy per cent. of the strength of the plate, we may use a working stress of 7 000 lb. per square inch.

Even with lock bar pipe it may be prudent to reduce the working stress below 9 000 lb., and this is more readily done because the added thickness of metal costs so little.

In the Springfield 42-in. lock bar pipe line, the maximum stresses under working conditions obtaining in the pipe line are as follows.

Above Provin Mt., Ordinarily Protected from Water Ram.			Below Provin Mt., Subject to Ordinary Water Ram.	
Thickness of Plate, In.	Maximum Static Head, Ft.	Corresponding Stress in Steel in Lb. per Sq. In.	Maximum Static Head, Ft.	Stress in Steel, Lb. per Sq. In.
$\frac{1}{4}$	243	8 840	...	.....
$\frac{5}{16}$	298	8 700	236	6 860
$\frac{3}{8}$	351	8 530	284	6 900
$\frac{7}{16}$	...	.....	347	7 250

It may be thought that these stresses are unnecessarily low and that thinner plates might have been used with perfect safety. But the pipe is relatively cheap and the advantage of having it so strong that there is not even a remote probability of its being broken by water ram that may sometimes occur in excess of the one that is calculated is worth getting.

Important lines of steel pipe have been designed with working stresses on steel of 12 000 to 13 000 lb. per square inch, but this has been with triple riveted double butt-strap riveting, and for lines absolutely protected from water ram.

In conclusion, it is my impression that up to the present time practice with steel pipe and cast-iron pipe has been rather unequal. Steel pipe has been made stronger than cast-iron pipe, but this has been justified by the cheapness of the material, by the lack of certainty regarding some of the conditions, and by the advantage of having the pipe strong beyond any possible question.

DISCUSSION.

Mr. Leonard Metcalf.* Mr. President, it seems to me that Mr. Hazen has done us a genuine service in bringing this matter to our attention, for it is one of great importance. Of course most works have pipes which are of comparatively small diameter, where these influences of which he has spoken are not so serious. At the same time there are enough pipe lines, particularly in our larger cities, to make the matter of importance, bearing in mind the heavy damages which result from failure of pipe lines. I would like to ask Mr. Hazen at about what point he finds that the influences of the depth of backfill affect the pipe. He spoke of 36-in. and larger; isn't the limit, perhaps, somewhat below that?

I have laid Class A, 20- and 24-in. pipe to a depth of about 20 ft., if I remember rightly, which are doing good service to-day, — the depth varying from 5 ft. to twenty-odd feet in a line about eight miles in length, running through the fields and woods.

There was a case of failure in a 42-in. pipe line of the Pennsylvania Water Company. Mr. Kuichling brought this same matter to my attention a year or two ago and spoke of that pipe line as furnishing a very good example of the effect of the backfill. The backfill was only, I think, something like four or five feet, and yet that pipe line broke and had to be replaced. There was some considerable expense in making good the damage done by the

*Of Metcalf and Eddy, Consulting Engineers, Boston, Mass.

break, and a long line of the pipe was taken out and replaced with pipe of heavier weight.

The President. I don't know whether it would help any if I related a little experience which I had with drain pipe. I found that by very careful tamping on the horizontal diameter and below we could add a great deal to the strength of the drain pipe, that is, to its power to resist the pressure of the backfill. I had the pipe put in and it failed; and I had it put in again and great attention paid to the ramming of the earth below and at the sides of the pipe, and it then stood the pressure of the fill. It seems to me that ramming the earth well opposite the horizontal diameter of the pipe will help it to resist the thrust and cause it to stand a great deal more pressure.

Mr. Robert S. Weston.* I would like to ask Mr. Hazen if he does not think that the relative greater liability of the steel plate to corrosion has influenced the choice of the thickness of the plates to some degree in another form, — even to increase the thickness beyond what is absolutely necessary.

Mr. Allen Hazen. Replying to Mr. Metcalf, it is obvious that the stresses that it was the object of my paper to call attention to will also exist in pipe less than 36 in. in diameter, but they will clearly be more important in large pipe than in small pipe. I have not attempted to set a limit to the size of pipe for which they should be taken into account, but as the matter is much more important for large pipe I thought it best to limit the discussion for the present to such pipe. I have endeavored to present a subject that seems to me to be of the very greatest importance, and that has been, as far as I know, largely overlooked in the design of cast-iron pipe, with the object of getting it discussed and of finding how far it should properly enter into future designs. When we are through with the discussion it may be that an answer to Mr. Metcalf's question will be found.

As Mr. King suggests, ramming the backfill on the sides increases the stability of the pipe. Professor Talbot's paper discusses this very well, and it may be read with profit by all interested in this subject. Having the material packed firmly against the sides and quarters of the pipe is more important than having

* Sanitary Expert, Boston, Mass.

a support underneath. In fact, the ideal position of a pipe would be to have it supported so firmly on the quarters that it would not bear underneath at all.

Mr. Weston's questions are largely answered in the paper itself. Steel pipe has frequently been made thicker because of anticipated corrosion, but I am disposed to think that generally it will be better for us to put the money that otherwise might be spent in thicker plates, in better coating and better inspection of the plates for surface defects, and into better devices for protecting the pipes against stray electric currents.

Mr. Emil Kuichling* (*by letter*). This paper is a very valuable addition to the literature of the subject, as it brings out clearly some of the defects in the usual formulas for computing the thickness of water pipes, and indicates how a more rational formula should be made. In dealing with the internal pressure due to water ram, the author states that such pressure is practically limited by the fact that the closing of a stop valve or gate in a large pipe ordinarily requires considerable time. Such gates are usually geared in the ratio of 3 or 4 to 1, and there are generally three screw threads per inch on the stem, thereby requiring from nine to twelve revolutions of the operating pinion to lower the gate disk one inch. When the bottom of the disk reaches the axis of the pipe, an appreciable hydraulic pressure against the disk begins to develop which causes friction on the guides and corresponding resistance to the turning of the stem. This resistance increases rapidly during the last quarter of the descent, so that the final inch may require the utmost exertion of three or four men for at least one minute. Against a static pressure of 50 lb. per sq. in., about twenty minutes are needed to fully close a 24-in. valve and thirty minutes for a 36-in. valve.

The writer has made a number of observations of the increase of pressure caused by closing a 24-in. stop valve in a long line of 24-in. cast-iron pipe. The point of observation was 2.53 miles from the supplying reservoir, the valve was 2 100 ft. beyond, and while the valve was shut the static pressure at said point was 49 lb. Before closing the valve the hydraulic pressure was 40.2 lb., and the water was flowing through the pipe with a mean velocity

* Consulting Engineer, New York.

of 3.45 ft. per second. The valve was closed as rapidly as possible in about twenty minutes, and during the last four minutes the pressure rose to a maximum of 65 lb., after which it oscillated rapidly from 40 to 64 lb. for a few seconds and then gradually reduced in two minutes to a range from 42 to 57 lb. In the course of eight minutes more, the range was from 46 to 52 lb., with increasing intervals of time between the pulsations, and at the end of fifteen minutes the pressure varied little from 49 lb. These observations were repeated several times subsequently with the same general results, and hence it was concluded that for long and large pipe conduits, the water ram caused by closing a stop gate would not induce an internal pressure greater than 1.5 times the static pressure.

In the small distributing pipes of a municipal water works, water rams of much greater magnitude may be expected by the rapid closing of fire hydrants and hydraulic motors of large size; but as this subject is not under consideration, further reference thereto will be omitted. It may also be remarked that stop valves larger than 24 in. in diameter are usually provided with by-pass valves which are closed after the main valve has been shut and the velocity of the water in the pipe has been greatly reduced; and if by carelessness the by-pass gate happens to be closed, the men who attempt to close the main valve will usually become aware of the fact during the latter part of the operation by the increased frictional resistance of the large valve stem.

The stresses caused by the weight of the backfill are highly important and vary much with the condition of the material in regard to moisture. Even when the material is well compacted by ramming, a settlement usually occurs after water has percolated freely into it, and with such settlement a greater load upon the pipe must ensue. Little is yet known of the magnitude of this external pressure, or of the manner in which it is distributed over the upper surface of a large pipe. So far as the writer is aware, the only experimental data that are available in this direction are those that pertain to the deformation or flattening of a few cast-iron and riveted steel pipes, the former being given in Prof. A. N. Talbot's Bulletin No. 22 of the University of Illinois, 1908, and the latter in the paper of D. D. Clarke, chief engineer

of the Portland, Ore., water works, in Transactions of the American Society of Civil Engineers, Volume XXXVIII (1897), pages 93–114, together with some observations made by the writer at various times between 1874 and 1896.

In view of the fact that settlements of the backfill usually appear to extend nearly uniformly across the entire width of the trench, the writer has assumed that the pressure thus induced upon the upper surface of the pipe is distributed uniformly in a vertical direction over its width and that no considerable pressure is exerted horizontally against the sides of the pipe; also, that the pipe bears uniformly upon its earthen foundation in the same manner as the backfill on the top. These assumptions, moreover, facilitate the computation of the bending moments, stresses, and deformation in a ring-shaped section. On this basis the formula for the magnitude of the elastic flattening or reduction (y) of the vertical diameter of a relatively thin pipe becomes: $y = \frac{WD^3}{96EI}$, where W is the uniformly distributed external load acting vertically on the pipe per unit of length; D is the mean diameter of the section, or the internal diameter plus the thickness, t; E is the modus of elasticity of the metal of which the pipe is made, and I is the moment of inertia of the longitudinal section of the wall of the pipe per unit of length, which is expressed by $\frac{t^3}{12}$. For the cast iron of the 36-in. and 48-in. pipes used in his experiments, Professor Talbot deduced the approximate average value E = 11 000 000 lb. per sq. in.; and for wrought-iron and steel plates the writer has assumed the usual mean value E = 30 000 000 lb. per sq. in. The weight W may also be expressed by $W = wD$, where w is the equivalent vertical load in pounds per unit of area. Taking the inch as unit and replacing I by its value $\left(\frac{t^3}{12}\right)$, we now have —

$$y = \frac{wD^4}{8Et^3}, \text{ whence } w = \frac{8Et^3y}{D^4},$$

which is the expression for the uniformly distributed vertical load or weight of backfill in pounds per square inch of horizontal surface required to produce a given deformation or reduction (y) of the vertical diameter of the pipe.

The values of w thus computed from the observed values of E, t, y, and D may now be compared with the observed or estimated weight w_1 per square inch of the backfill, and the writer has arranged some of the available data in the following table, in which the first four items refer to cast iron, and the remainder to soft steel pipes.

Internal Diameter. In.	Thickness (t). In.	Mean Diameter (D). In.	Deformation (y). In.	Estimated Load (w_1). Lb. Sq. In.	Computed Load (w). Lb. Sq. In.	Ratio $\frac{w}{w_1}$.	Backfill.
48	1.25	49.25	1.00	37.2	29.2	0.785	S*
48	1.50	49.50	1.00	57.2	49.4	0.864	S*
36	1.00	37.00	0.80	49.6	37.5	0.754	S*
36	1.25	37.25	0.50	63.8	44.6	0.700	S*
42	0.238	42.238	0.438	2.92	0.445	0.153	S*
42	0.203	42.203	3.50	4.69	2.216	0.472	SC†
42	0.203	42.203	2.75	4.69	1.741	0.372	SC†
42	0.203	42.203	1.00	3.61	0.633	0.175	WS‡
42	0.203	42.203	0.563	2.92	0.356	0.122	S*
35	0.203	35.203	3.00	3.13	3.922	1.255	SC†
33	0.203	33.203	0.375	3.19	0.620	0.194	S*
33	0.203	33 203	0.188	1.67	0.310	0.186	S*
38	0.25	38.25	2.00	5.83	3.504	0.600	WC§
38	0.25	38.25	1.50	5.83	2.628	0.450	WC§

* Weight of dry sand given at 80 lb. per cu. ft. S = Dry Sand.
† Weight of sandy clay estimated at 90 lb. per cu. ft. SC = Sandy Clay.
‡ Weight of wet sand estimated at 100 lb. per cu. ft. WS = Wet Sand.
§ Weight of wet clay, etc., estimated at 120 lb. per cu. ft. WC = Wet Clay and Stones.

The values of the ratio $\left(\frac{w}{w_1}\right)$ in the foregoing table exhibit a wide variation, as is to be expected. In the case of the 35-in. steel pipe, it is probable that the filling under the lower quarters of the pipe was not well done, and that the pipe rested mainly on a narrow strip of the bottom, whereby the deformation was greatly increased.

Where a good support on the bottom is given by dry or well-tamped sand, it seems that the external load due to the backfill may be taken at from one fifth to one half the weight of the material, distributed uniformly on the horizontal projection of the pipe, when the depth of covering is from 3 to 7 ft.; but when the backfill is heavily loaded, a corresponding addition must be made, as indicated in the case of the cast-iron pipes. The data are not sufficiently numerous and diversified to give a clear view of the matter, as so much depends on the nature of the backfill and the

way it is placed under and over the pipe; hence until further investigations have been made, it will be prudent to assume that in locations where the right of way for a pipe conduit is not affected by heavy moving loads, such as locomotives, road rollers, etc., at least two thirds of the weight of the backfill acts upon the pipe as a uniformly distributed vertical load and produces circumferential bending stresses in the metal.

The magnitude of the maximum stress s in the outermost fiber, due to the said uniform vertical external load (w), is found by placing the moment or modulus of resistance equal to the maximum bending moment: $M = \frac{wD^2}{16} = \frac{st^2}{6}$, whence $s = 0.375w\left(\frac{D}{t}\right)^2$. Now, if we assume that the backfill weighs 115 lb. per cu. ft. and is 6 ft. deep, the weight will be $w_1 = 4.8$ lb. per sq. in.; and if two thirds thereof acts vertically upon the pipe as aforesaid, the value of w will be $w = \frac{2}{3}w_1 = 3.2$ lb. per sq. in., whence $s = 1.2\left(\frac{D}{t}\right)^2$. In general, the ratio $\left(\frac{D}{t}\right) = 37$ for the thinnest large cast-iron pipes and 193 for the thinnest large steel pipes; hence we have in general the maximum stress due to bending, $s = 1\,643$ lb. per sq. in. for cast iron, and $s = 44\,699$ lb. per sq. in. for steel. This latter value of s is greater than the elastic limit of the metal, and hence the pipe will become permanently flattened unless a considerable horizontal pressure is exerted on the sides of the pipe. From the foregoing experimental data it does not seem expedient to regard the ratio $\left(\frac{w}{w_1}\right)$ as being less than 0.25 under the most favorable conditions, and if the weight of the backfill is only 96 lb. per cu. ft. with a depth of 3 ft., we will have $w = \frac{w_1}{4} = 2.0$ lb. per sq. in., and $s = 0.75\left(\frac{D}{t}\right)^2 = 27\,937$ lb. per sq. in. for the thinnest steel pipes. These figures will suffice to show that the stresses caused by the backfill are of much importance when the pipe is empty or internal water pressure is small.

The question now arises whether the tensile bending stress due to the backfill is to be added to the tensile stress resulting from the internal water pressure, or whether the latter does not

eliminate the former in large degree by reducing the initial deformation or flattening. There can be little doubt that a large internal water pressure will tend to restore the original circular cross-section of the pipe, but in doing this work the sides of the pipe will recede slightly from the adjacent earth and thus reduce or eliminate any existing lateral horizontal pressure. This action must be followed by a corresponding increase of the vertical external pressure until equilibrium is finally established with a somewhat greater external load than while the pipe was empty, and hence also with a slight deformation and a resulting tensile stress that will add to the stress produced by the internal water pressure. It is difficult to determine the magnitude of this final flattening and its accompanying tensile stress. In the case of cast-iron pipes it will usually be small, but in the case of thin steel pipes it may attain a considerable magnitude. Under existing conditions of inadequate experimental data, it will, therefore, be prudent to consider that the backfill will produce an appreciable deformation and tensile stress in large water pipes, as done in Mr. Hazen's formula.

Another feature in the case is the external pressure of the atmosphere against the wall of a pipe from which the water has been withdrawn, as when a valve is closed and a blow-off is opened. The backfill is usually more porous above the pipe than below the same, so that momentarily a greater atmospheric pressure will develop on the upper surface than on the lower one when all internal pressure ceases; and if the material is moist and plastic, the air pressure on the surface of the backfill will act like an applied load at the rate of 14.7 lb. per sq. in., of which the greater part will be transmitted to the pipe. This atmospheric pressure is equal to the weight of a column of earth 22 ft. high at the rate of 96 lb. per cu. ft. No provision for admitting air into cast-iron pipes by means of automatic vacuum valves is usually made, but if we assume a depth of 10 ft. of backfill at 115 lb. per cu. ft. in conjunction with the atmospheric pressure, the total external load will become $w_1 = 23$ lb. per sq. in.; and if three fourths of this load acts vertically upon the upper surface of the pipe, as indicated by Professor Talbot's data in the foregoing table, we will have w = 17.25 lb. per sq. in., and the cor-

responding stress $s = 0.375w\left(\frac{D}{t}\right)^2 = 8\,857$ lb. per sq. in. in the thinnest cast-iron pipe for which the ratio $\left(\frac{D}{t}\right) = 37$. This is an extreme case, as there will be a little air pressure on bottom of pipe, owing to the density of the material and the high resistance to the circulation of air therein.

Severe circumferential stresses are also caused in cast-iron pipes by the settling of several lengths. This produces an intense leverage pressure in the lead joint on the top and bottom of the spigot, with the probability that the fillet or bead comes in contact at the top with the bell, thus making a concentrated load of great magnitude. If we assume that this vertical load is not concentrated, but is distributed uniformly over the horizontal diameter D and on an effective width of 2 in., and is resisted by a length of $b = 12$ in. of the spigot end of the pipe, we will have the relation $M = \frac{2wD^2}{16} = \frac{sbt^2}{6} = 2st^2$, whence $w = 16.s\left(\frac{t}{D}\right)^2$. Taking the stress s at its limiting value for cast iron in flexure, viz., $s = 27\,000$ lb. per sq. in., as per Professor Talbot's tests, we will have for a 36-in. cast-iron pipe 1 in. thick a limiting leverage load on the lead joint $w = 316$ lb. per sq. in. on width of 2 in. Such a load is very easily developed by the settling of a few heavy pipes in a yielding soil.

In addition to the computable stresses mentioned in the foregoing, there are a variety of other stresses that should be taken into consideration, as cited in Mr. Hazen's paper. Concerning the magnitude of these other stresses, little information of a definite character is available, and hence allowance for them must be made in the adopted factor of safety. Mr. Hazen has shown very good reasons for modifying our previous formulas for the thickness of large cast-iron pipes, and submits a rational substitute. The only point that the writer can raise is in regard to the ultimate tensile strength of that quality of cast iron which is now commonly used for making pipes. The author has adopted for this a value of 22 000 lb. per sq. in. Not many years ago water-works engineers were satisfied if the direct tension tests of samples of the metal showed an ultimate strength of about 16-

000 lb. per sq. in. For breaking stress in bending, values of from 30 000 to 40 000 lb. per sq. in. are often obtained, but as these figures are commonly based on the erroneous assumption that at rupture the neutral axis lies at the middle of the rectangular cross-section of the test bar, it is clear that they cannot represent the normal tensile strength of the metal which is brought into action by the internal water pressure. The use of $s = 22\,000$ thus implies a marked improvement in pipe foundry practice which deserves some explanation, and the author will add much to the value of his paper by submitting a brief abstract of recent tests of pipe metal on which his figure is based.

ARTHUR N. TALBOT, ESQ.* (*by letter*). Mr. Hazen has referred to the experiments on the strength of cast-iron pipe to resist external load made at the University of Illinois. It is evident from a study of the question that the actual bending moment brought upon pipe depends upon the method of applying the load (its distribution over the pipe) and upon the way the pipe is bedded. If the pipe is supported along the bottom element alone, and the load is applied along the top element, the bending moment at a longitudinal section at the top or bottom of the pipe will be $0.16QD$ where Q is the concentrated load applied at the crown and D is the diameter of the ring. If, now, the load is distributed uniformly in a horizontal direction over the pipe, and if the upward pressure on the bed is similarly uniformly distributed, the maximum bending moment is $\frac{1}{16}WD$ where W is the total vertical load on the pipe. Lateral pressure against the pipe will reduce this maximum bending moment. If this lateral pressure is uniformly distributed and if q represents the ratio of the horizontal to the vertical intensity of pressure, the maximum moment will be $\frac{1}{16}(1 - q)WD$, where W is the total vertical load on the pipe. It is seen that if the intensity of the horizontal pressure is the same as that of the vertical pressure, $q = 1$ and the bending moment becomes zero at all points. Any horizontal or lateral pressure if uniformly distributed will decrease the bending moment developed. However, study of tests made on pipe embedded in sand, and consideration of the conditions which will

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exist in the bed and in the back-filling of a pipe line, indicate that the effect of this lateral pressure may be expected to be offset by variations from uniform distribution of pressure on the bed or of the load on the pipe and, therefore, that $\frac{1}{16}$ is as low a coefficient as should ordinarily be assumed in calculating stresses. Under these assumptions the formula given by Mr. Hazen for the bending moment stress developed is correct, and probably it is as generally representative as can be made with our present knowledge. It may need modification for unusual conditions of bedding and backfilling, and of course in deep trenches the full weight of the earth may not come on the pipe.

The analysis given in Bulletin No. 22 of the Engineering Experiment Station of the University of Illinois, referred to by Mr. Hazen, brings out the importance of giving especial care to bedding and backfilling. It is very important that the pipe shall not rest along an element at the bottom, or that after a little settlement the main pressure shall not be upon this line. If the layer of earth immediately under the pipe is hard or uneven, or if the bedding at either side of the pipe is of soft material or is not well tamped, the result is greatly to increase the bending moment developed by the external load and hence to increase the tendency of pipe to fail. This condition may be aggravated in the case of a pipe with stiff bell or hub when settlement brings an excessive proportion of the bearing at the bell, resulting in a distribution of pressure far from uniform. In bedding the pipe in hard ground it is better to form the trench so that the pipe will be fairly free along the bottom element, even after settlement occurs, and in such way that the bearing pressure may be greatest near the one-third points of the horizontal diameter, or even farther out. Care in this matter will reduce the bending moment stresses in the pipe.

In case the pipe is bedded in loose material, the effect of settlement will be to compress the earth immediately under the bottom element of the pipe more than at either side, with the result that the pressure will tend toward concentration at the center. Careful filling and tamping at the sides will result in giving lateral support to the pipe. In a similar manner the filling and tamping over the top may be made in such a way as to

reduce the bending moment stresses — the fill should be more thoroughly compacted at the sides and over the quarter than over the top of the pipe.

Attention should be called to the fact that the analysis of effect of external load assumes that the distribution of the pressure is by means of the earth under and over the ring and that this earth will be compressed in somewhat the same way as other materials of construction under compression. Unless the earth has elasticity, the assumed distribution of pressure cannot occur. Further, to secure the uniform distribution assumed, the pipe itself must deform enough to allow for the movement of the earth which takes place under this compression. This is especially true with reference to the presence and utilization of lateral restraint, and a ring which does not deform laterally will not develop lateral pressure in the adjoining earth under ordinary conditions of moisture and filling to any great extent. As the conditions of earth and moisture produce mobility and approach hydrostatic conditions, the necessity for this elasticity and movement does not exist, but here the lateral pressure approaches the vertical pressure in amount and the bending moment becomes relatively smaller.

Enough has been said to indicate the importance of care in bedding pipe and in filling over them and to indicate the great difference in the amount of bending moment stresses developed with different conditions of bedding and filling. Where there is any question of needed strength, it will be money well spent to use especial care and precaution in bedding the pipe and in filling around and over it.

Mr. Hazen refers to the smaller liability of steel pipe to breakage. One factor which gives additional security to the steel pipe, and which has not been recognized, is the advantageous distribution of external pressure above and below and laterally, due to the larger deformation under external load. Under the distortion of section the pressure will be greater at points away from the top and bottom element and the lateral pressure against the pipe will also be greater. The change in the horizontal and vertical diameters of a steel pipe 0.2 in. thick will be seventy-five times as great as that of a cast-iron pipe 1 in. thick under the same

load and with the same distribution of pressure. The higher deformation will permit the development of lateral pressures which will much reduce the bending moment stresses brought upon the pipe by the external loads. Although the tests heretofore referred to show that 48-in. cast-iron pipe will give a change in diameter of from $\frac{1}{2}$ in. to $1\frac{1}{2}$ in. before breaking, the amount of change in diameter where internal pressure constitutes the principal force producing stress will be slight, and the yielding of the earth will not be sufficient to permit the development of much lateral pressure. In thin steel pipe the change in diameter under ordinary loads is greater. This point, of course, is only one item in any comparison of steel and cast-iron pipe.

It does not seem logical to make the allowance for water hammer in a pipe line dependent upon the amount of the static pressure, as the conditions of pipe line flow vary so greatly, and especially as the amount of water hammer developed depends upon velocity of flow rather than upon the static pressure existing.

Mr. Hazen is to be commended for calling attention to the importance of the stresses due to external load in large pipes subjected to low internal pressure. The paper is an interesting presentation of the matter.

Mr. W. C. Hawley * (*by letter*). This paper calls attention to a fact which, while it has been understood by a few engineers, has not been generally recognized by the average water-works man. Up to a certain diameter, the external pressure, so far as the weight of the backfill is concerned, need not be considered, but just what this limiting diameter is has not been stated. It is the writer's belief, however, that the author, in considering pipes 36 in. in diameter and larger, has indicated the point at which the weight of the backfill must be considered, except, possibly, in those cases where the pipe is laid at excessive depths. This is borne out by the experience with the Pennsylvania Water Company's line to which Mr. Metcalf has referred. This line was laid for the purpose of conveying water from one distributing reservoir to another, and two miles of it were of 42-in. pipe, the other two miles being of 30-in. pipe. The 42-in. pipe was laid with an average depth of cover to top of pipe of about 4.5 ft.,

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but there were a number of places where for short distances it was from 9 ft. to 12 ft., and in two cases it was at least 18 ft. The water pressure on this line reached as high as 150 lb. per sq. in. There were but two weights of 42-in. pipe used: Class A, which weighed 400 lb. per ft., with a thickness of approximately 0.86 in., and Class B, which weighed 450 lb. per ft., with a thickness of approximately 0.97 in. The deep trench, with one exception, occurred on the B class of pipe. The exception was that with 18-ft. cover near the first reservoir, and it is interesting to note that two of the light-weight pipe failed in this deep trench.

The serious trouble on this line, however, occurred with the Class B pipe at a point where the pressure was in the neighborhood of 125 lb. and where the backfill did not exceed from 3 to 5 ft. The failures were so serious that a mile and one half of the 42-in. pipe were taken up and replaced with 36-in. pipe.

The two miles of 30-in. were of a uniform weight of 250 lb. per ft., with a thickness of about 0.82 in. This pipe was laid with an average depth of cover of about 4 or 5 ft., but with maximum depths of 8 to 12 ft. The highest pressure carried was about 130 lb. to the sq. in., and the backfill at this point was only 2 or 3 ft. The weight of this pipe was calculated by the same formula that was used for the 42-in. pipe; it was purchased from the same foundry under the same specifications at the same time and neither was inspected at the foundry. Both pipes were laid in 1900 by the same contractor, and the 30-in. is still in service without a single failure due to any fault of the pipe. This would seem to indicate that the smallest diameter of pipe which requires the consideration of the external pressure lies between 30-in. and 42-in. It is interesting to note, however, that nearly all of the 30-in. pipe was laid in an earth trench with good material on which to place the pipe, while most of the trench for the 42-in. pipe was in stony ground or rock.

As above stated, there is about one-half mile of the 42-in. pipe still in service. Specifications under which this pipe was laid called for it to be laid on blocks. This was not done in all cases, but within the last fifteen months two pipes have burst on account of the concentration of the load at one point. In each case the pipe was resting on a projection of rock in the bottom of the

trench. In contrast to this, in the mile and one half of 36-in. pipe which was laid by the same contractor in the same trench after the removal of the 42-in pipe, but under rigid inspection by a man experienced in pipe laying and which was not laid on blocks, there has not been a single failure, not even a serious leak, in the eight years that it has been in service. The 36-in. pipe was, however, materially heavier than the 42-in. pipe.

The stresses from internal strains in the metal and the stress due to improperly bedding the pipe cannot and need not be taken care of in a formula for thickness of pipe. The former can be largely eliminated by proper inspection at the foundry by an experienced inspector. The latter requires good honest work in laying the pipe. The inspection necessary to secure the desired results will cost far less than the additional metal which will be required if allowance is made in the formula to cover them, to say nothing of the cost of damages and the annoyances caused by the interruption of supply after the pipe has been laid and put into service.

The thorough bedding of the pipe is a more important matter than is generally recognized. The writer had occasion some years ago to reconstruct a water-works plant and to materially increase the pressure on a portion of its distribution system. The pipe in this system, or at least a considerable part of it, had been laid to stand a pressure of not to exceed 90 lb. per sq. in. As a matter of fact, for years the pressure has seldom if ever exceeded 40 to 65 lb. Some of the 4, 6, and 8 in. pipe weighed respectively 20, 30, and 40 lb. per ft. With the completion of a new reservoir, the pressure was increased to from 125 to 165 lb. per sq. in. The pipes, though of light weight for such pressures, had been in the ground long enough to have become thoroughly bedded, and there were but two pipes burst as the result of increasing the pressure, both of which were light-weight 12-in. pipes. The writer is of the opinion that had this pipe system been subjected to such a high pressure when it was first laid, there would have been a large number of breaks.

There is a cause for the failure of cast-iron pipe which was very forcibly called to the writer's attention some years ago by a carload of pipe which had been in a railroad collision. The pipe had

been partially thrown from the car, some of it badly broken, other lengths merely cracked. It was reloaded and upon its arrival at its destination, the broken and cracked pipe was rejected. A very careful inspection was made of each length, and special attention was given to sounding each length as it hung supported from the derrick by striking it with a hammer. At least three men inspected the pipe on the ground before it was put in the ditch, with the result of still more rejections. As soon as the pipe was laid, it was tested under pressure and several lengths failed. An inspection of the breaks showed that the pipe had been cracked on the inside where it could not be seen by the inspector, but that the crack had not extended through the shell of the pipe. Doubtless the cause of the crack was a sharp blow received on the outside at the time of the collision, which had opened the crack on the inside of the pipe, but was not sufficient to cause a crack through the entire thickness of the metal. The writer's experience since that leads him to believe that a considerable number of the failures of cast-iron pipe are due to blows received in loading, transportation, or unloading, — especially unloading, — and that special care must be exercised to prevent pipe being damaged in this way.

The writer notes that in developing the formula for the thickness of cast-iron pipe, the author has used 22 000 lb. as the tensile strength of the metal. Doubtless he has information which leads to the use of this seemingly high figure. So far as the writer is concerned, he has for some years past used 18 000 lb., and from rather recent figures is inclined to believe that 20 000 lb. could be safely used.

Mr. Allen Hazen (*by letter*). The author will agree at once that the subject of "water ram" was treated in an inadequate way, as was perhaps natural, because it was not the main subject under discussion. The author hopes that a separate paper upon this subject may be presented by some one who is well qualified to do it.

The tensile strength of cast iron, taken in the calculation as 22 000 lb. per sq. in., is probably a little above that which can ordinarily be obtained at the present time. Mr. Hawley's suggestion of 20 000 lb. as representing the best current work is probably about right. The calculation was first made in con-

nection with a discussion in which it was proposed to use a superior quality of cast iron with a higher tensile strength, and the figures so made were not reduced, as perhaps it would be well to do now, in applying them to present conditions.

On the other hand, the average strength of the cast iron used in the culvert pipes broken in Professor Talbot's experiments, computed by solving the formula backward, gave an average value somewhat above the 22 000 lb.

The fact that lateral pressure is developed largely in connection with the deformation of the pipe, growing out of its elasticity, is an interesting one, and the points made by Professor Talbot and Mr. Kuichling, based upon this general idea, are most interesting and important.

Mr. Kuichling's data as to the weight actually borne in certain cases, computed from the measured distortion of the pipe, is most interesting. This seems to indicate in general a smaller proportion of the weight of the fill actually carried by the pipe than is assumed by the formula. However, the maximum results will control rather than average results, and bearing this in mind the substantial agreement between the formula and the observations is gratifying. Professor Talbot's endorsement of the general method is most important.

It is gratifying that Mr. Hawley has put on record particulars as to one of the lines of thin pipe that has broken badly. The author believes that there are a number of other cases of interest and importance known to members of the Association, and he hopes that further particulars of these may be put on record at some time.

THE MECHANICAL FILTRATION PLANT AT NEWPORT, R. I.

BY ROBERT E. MILLIGAN, MANAGER NEW YORK CONTINENTAL JEWELL FILTRATION COMPANY.

[*Read December 14, 1910.*]

The reinforced concrete filtration plant of the Newport Water Works, Newport, R. I., was contracted for in the early part of 1909 and completed and placed in operation in May, 1910.

Considerable elasticity in operation is possible because of the design of this plant, as sedimentation with or without coagulation, separate coagulation within the basin provided, sterilization by hypochlorite solution before or after filtration, and aëration are all arranged for in conjunction with mechanical filtration proper.

The plant consists essentially of two sedimentation or settling basins arranged to operate as one basin under normal conditions, a distinct coagulating basin through which the settled water must pass to the filters, the filters themselves and the clear water well below them.

Fig. 1, Plate I, shows the general design and relation of these settling basins and the coagulating basin to the filters proper which are contained within the house shown in the middle distance, the background indicating the pumping station of the water works, to which the new structure is joined by a covered passage and machinery room. The settling basins are arranged around three sides of the coagulating basin and the coagulating basin is located within the space indicated by the iron railing shown on the picture. The basins together occupy a rectangular space approximately 135 ft. long by 70 ft. wide, and the center coagulating space is 84 ft. by 25 ft. The settling basins are about 19 ft. deep and the coagulating basin 16 ft. The tower shown is the coagulating portion of the building providing gravity feeds for the solutions used in the purification process.

FIG. 1.

ARRANGEMENT OF SETTLING BASIN AND COAGULATING BASIN IN RELATION TO FILTERS.

FIG. 2.

COMPLETE SEDIMENTATION AND COAGULATING BASIN BEFORE SUPERSTRUCTURE WAS ERECTED.

Fig. 2, Plate I, shows the completed sedimentation and coagulating basins, filter tanks, clear well, and machinery room all enclosed before erection of buildings. The elevated structure shown above the basin contains the concrete storage tanks, four in number, for the sulphate of alumina and hypochlorite of lime solutions. The building in the background is the pumping station, and the sheet of water shown is one of the supplies of the water works, in fact, the receiving basin or impounded reservoir from which the low-service pumps supplying the filters take their suction.

As you probably know, Rhode Island has few hills and consequently a limited watershed, so that large impounded areas are used to provide the supply for Newport. These supplies are connected together, and to the receiving reservoir shown adjacent to the pumping station. A special pumping station is in use occasionally to force the water from one of these reservoirs to the receiving basin because of an intervening hill. Newport's water supply is carefully guarded against pollution, large areas of water-shed being owned by the company. From the viewpoint of filtration, however, this is a difficult water to handle, as most of the supply is high in color Portions of the supply differ radically from each other in character. All of it is low in alkalinity, and algal growths at certain times prevail.

The report of the State Board of Health for July, 1910, states that considerable micro-organisms were present, including desmids, protozoa and nostoc, crustaceans and amorphous matter. These continued through August, while the report of November includes asterionella, pediastrum, and scenedesmus. At that time, November 15, 1910, the report shows the raw applied water to have a color of 43 and 330 bacteria per cubic centimeter, and the treated filtered water to be 5 in color and had no bacteria per cubic centimeter.

Our own chemist, Mr. Nichol, now in that neighborhood, writes me that he finds scytomena in quantities clinging to the filter walls.

These difficulties were foreseen and influenced the design, Dr. J. L. Leal, who acted as adviser to the water works and supervised the design of the plant, wishing all the latitude possible to meet and remove these disadvantages.

Constructively, the plant is an excellent example of reinforced concrete; it might rather be described as concreted steel.

Fig. 1, Plate II, gives an idea of the very thin reinforced beams tying the open coagulating and sedimentation basins together in place of decks, and indicating the concrete flume opening through which the subsided water passes to the coagulating basin and then to the filters by gravity. There are 1 640 cubic yards of concrete of the proportion 1 : 2 : 4, and 76 tons of corrugated type D steel bars used, the steel being approximately 0.7 per cent. of the bulk of the concrete. The capacity of the sedimentation basin is 750 000 gallons, or three hours' continuous subsidence at the normal filtering value of 6 000 000 United States gallons in twenty-four hours. In addition, the capacity of the coagulating basin is 250 000 gallons, or a period of one hour's coagulation; the total capacity for subsidence and coagulation is therefore 1 000 000 gallons, or a period of four hours from the time the water enters the settling basin until it reaches the influent flume to the filters.

Within the space connecting the pumping station with the new filter building is arranged the low-service machinery rooms.

This room (Fig. 2, Plate II) is on a level with the old pump room, elevation 14.43, about 7 ft. below the operating floor of the filter house, elevation 21.25, so that it is easily reached by the engineer in charge, and also forms the entrance to the filter house. In this machinery room are located two 6 000 000-gallon centrifugal pumps, each direct connected to vertical Sturtevant engines, and these pumps supply the sedimentation basins with the water to be purified, pumping first to two large aërating devices, one on either side of the two settling basins, and superimposed above them and partly supported on the filter deck. In this room also is located the blower furnishing air to assist in washing the filters, and the two cast-iron float tanks with levers operating the balanced valves on the steam supply to the engines; these float tanks are connected with the level of the water in the coagulating basin so that the pumps increase or diminish the supply automatically. And here, too, is located the testing table disclosing the water passing from the filters, and the raw water as well

At times considerable odor exists in the raw supply, rendering a very thorough aëration necessary before it passes to the filters.

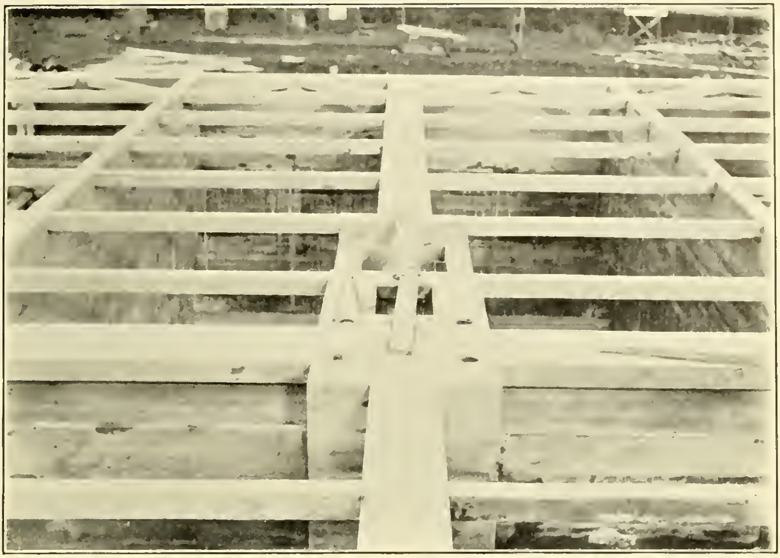

FIG. 1.
SURFACE OF COAGULATION BASIN SHOWING FLUME ENTRANCE.

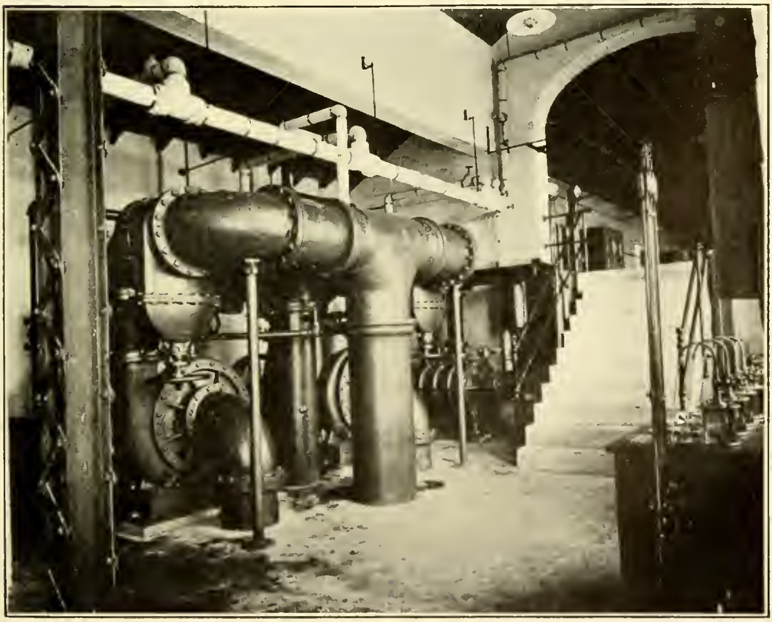

FIG. 2.
LOW-SERVICE PUMPS.

The aërating devices (Fig. 1, Plate III) are, I think, novel and certainly have proven successful in the results obtained. They consist of substantially two large concrete boxes, each with two sides or slabs converging to a common center. On these slabs rest certain cast-iron sections about 2 in. square. These sections are ridged in such a manner that when bolted together, covering the entire surface, the whole presents a series of channels abutting one against the other and forcing the incoming water to take a tortuous tangential direction, and making a multiplicity of miniature water falls over which the water dashes, reaching the channel at the bottom of the converging slabs thoroughly aërated and without further cost than the extra lift of about 4 ft. implies. The collecting channel then permits the water to pass into the settling basins and eventually to and through the filters, passing through Weston controllers located in the pipe gallery, finally to the clear water well under the filter house whence the high-service pump lifts it to the consumer.

The pipe gallery is lighted by electricity, is spacious and easily entered by a door leading from the machinery room.

Fig. 2, Plate III, shows the operating floor above the pipe gallery before the building was erected. The filter bed openings and the line of the building is also indicated. On the right is located one of the aërators.

The same space is shown in Fig. 1, Plate IV, after the erection of the building and installation of the operating tables. Here the laboratory room is located. At the upper end of the operating gallery, and beyond the laboratory, is the storage space. Storage and mixing tanks with agitators are arranged in a gallery elevated above the main floor, while on the main floor are located the orifice and regulating devices for the feeding of coagulant and hypochlorite solution.

On the operating floor, the loss of head gages are installed adjacent to the operating tables. These tables are constructed of black slate, and the indicators and valve handles are nickel plate, the whole adding to the appearance of the gallery.

The filter house proper opens into the coagulant tower located just above the end wall of the coagulating basin (Fig. 2, Plate IV). In this tower are arranged all the coagulant devices; the upper

portion of the tower or gallery contains the two hypochlorite of lime tanks and the two sulphate of alumina tanks, all four of reinforced concrete, each 7 by 7 by 5 inside. By means of a hoist and bucket the sulphate of alumina is lifted in measured quantity and laid upon the racks and water sprayed upon it until dissolved, and the concrete storage tank filled to a prearranged point, whereupon the water automatically shuts off, and the stored solution, 2 per cent. strength, is ready for use; this solution, kept in motion by agitators, then feeds into a porcelain-lined cast-iron orifice box located below and in measured quantity is introduced from there into the raw water at two points if required, namely, the suction of the centrifugal pumps and the influent flume to the coagulating basin. While the hypochlorite solution is also used and stored as a solution and fed through similar orifice feed boxes, the handling of the salt itself is somewhat different in order to get it into the storage tank with the least exposure. Superimposed above the concrete storage tanks are two cast-iron porcelain-lined mixing tanks with tight covers and equipped with agitators, revolving at a faster rate than is necessary for those used in the storage tanks.

The hypochlorite is placed in these mixing tanks and thoroughly agitated with a small stream of water passing in and out to the storage tank, the storage tank meanwhile slowly filling to the point required. The hypo. is thus kept in a sort of chyle or milky solution, gradually weakening in the mixer and passing to the storage tank where the slower moving agitator keeps it thoroughly mixed. Little or no odor is noticed around this process, the mixing occurring but once a day.

Preliminary operating by us soon established the fact that introducing the hypo. into the raw water had no apparent effect even when quantities sufficiently large to convey distinct odor of chlorine to the filtered water were used. No reduction of bacteria or color was apparent and no appreciable elimination of algæ was noticed.

When coagulation with sulphate of alumina was accomplished by its introduction as the water entered the settling basin, and the coagulated water was filtered in the usual manner so that perfectly clear water greatly reduced in bacteria passed into the clear water

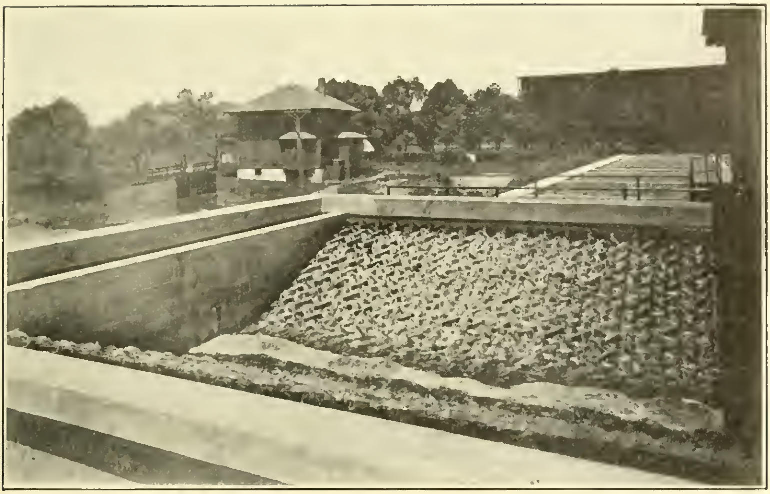

FIG. 1.
AËRATING DEVICES.

FIG. 2.
FILTER OPERATING FLOOR AND FILTER BEDS.

Fig. 1.
Operating Floor.

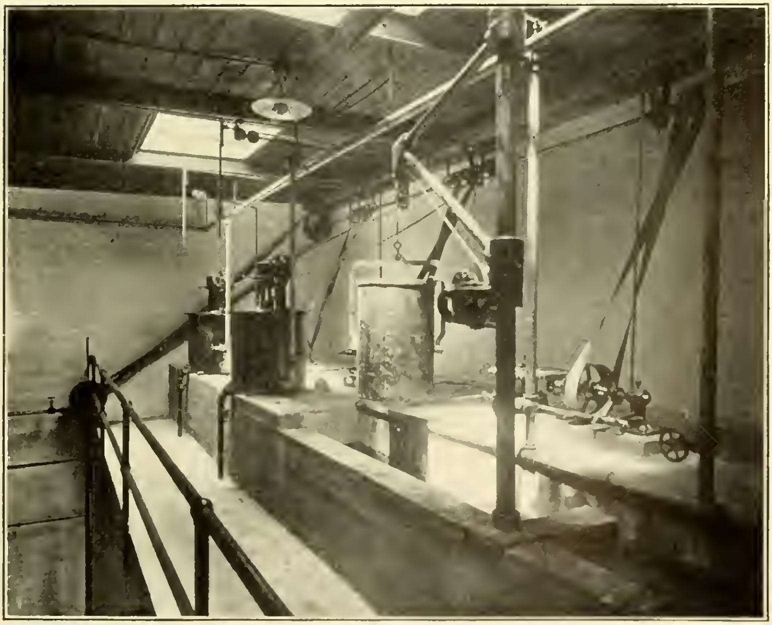

Fig. 2.
Coagulant, Hypo-Storage, and Mixing Tank.

well, and the hypo. solution in minute quantities was fed at a point in the clear well at the sump or suction to the high-service pumps, the desired result was attained and practically sterile clear bright filtered water was pumped to the consumer.

At the time the above-quoted State Board of Health analysis was made, November, 1910, one grain per gallon of sulphate of alumina was fed to the discharge of the low-service centrifugal pumps, and 0.5 parts per million of hypochlorite of lime were applied at the sump or outlet of the clear water well.

The capacity of the clear water well is 116 000 gallons, and covers the entire basement of the filter plant proper. These are six 1 000 000-gallon filters of the Continental air wash pattern, each discharging separately into it so that the one point where all the filtered water comes into intimate contact with all the hypo. fed through one connection is at the outlet of the basin where the high-service pumps take their suction.

The officers of the water works gave every assistance, and the thanks of the contractors are especially due Mr. E. W. Kent, chief engineer and superintendent, who supervised the construction for the Water Company, and under whose direction all the mains exterior to the building were laid and all the excavation accomplished.

WATER CONSUMPTION AND STATISTICS RELATING THERETO.

BY EDWARD S. COLE, CONSULTING ENGINEER, NEW YORK.

[Read March 9, 1910.]

It is not my purpose to discuss the broad subject of water consumption, but rather to plead for a more rational method of reporting the statistics of water use in American cities.

The need of better data has been appreciated keenly by all who are interested in the improvement of American works along lines of economy and efficiency. We in this country are very late to take up the conservation of our water supplies, however advanced we consider ourselves in other fields. Without doubt we must sooner or later find ourselves obliged to practice economy in water-works matters just as have our English cousins, and the certainty that this change is coming is the chief argument in favor of better water supply statistics, such as will give us the much-needed measure of relative economy.

Our cities may be wasteful or economical in water use, but there is no competent evidence of the fact available to-day. Per capita consumption as we have it is of little or no value to the water-works man, whether he be interested in the operation of old works or the design of new ones, for the excellent reason that it has been our time-honored custom to lump business and domestic consumption. Obviously it is futile to compare total per capita ratio of consumption without first excluding business use. It needs no argument to show that "business use" bears no rational relation either to population or to anything else. It is an independent variable with which it is impossible to solve the great problem of reasonable use in American cities. In the name of common sense let us eliminate it!

We are all familiar with examples of variable use, for we have the suburban town with little or no such use and the mill town

with a disproportionately large amount drawn for manufacturing purposes.

It is plain that we must separate business and domestic consumption if we would make comparisons. Even in our large cities, business use varies greatly, though but few reliable estimates of it have been made; probably a variation of two hundred per cent. is quite possible. The twenty-five gallons per capita estimated by Mr. Brackett as used for business purposes in Boston is hardly a criterion for similar use in New York, Pittsburgh, Buffalo, or Chicago.

Right here let me say that we cannot be too cautious in reporting the total amount drawn for business purposes. Even when entirely supplied through meters we must accept the figures subject to an increase because of the widespread fondness of the American manufacturer for getting ahead of the local water department. That large meters *are* by-passed, or water drawn from fire services or other unmetered connections, is beyond question and to an extent not realized by many superintendents. Speaking from a personal knowledge gained in making district tests in many cities during the past ten years, I do not hesitate to say that this sort of thing is responsible for much of the apparent unreasonableness in reported statistics as well as for great financial losses to city revenues.

Incidentally let me add that such losses need not continue, for there are several well-known means for detecting them. Is it not possible that a few of our cities which enjoy the distinction of reporting a low per capita rate are more indebted to a fortunate combination of circumstances, such as a large tenement-house population and non-water-using mills, than to unusual efficiency of management?

How often have we as outsiders misjudged a city reporting an apparently excessive total rate, when as a matter of fact there are special large business or other uses which justify that rate.

As to domestic consumption we also find a variation, but it seems to bear a more or less rational relation to the character of the consumers.

Here we find according to published statistics of metered consumption a range from ten or twelve gallons per capita daily for

the tenement-house dwellers with their scanty supply of fixtures and unsanitary habits of living, to eighty or ninety gallons per capita for the finest residences and city apartment houses.

Obviously it would be fair to divide domestic use according to three general classes representing the highest, middle, and lowest rate of use without involving unnecessary complication. Such a classification would throw a flood of light upon the whole matter of relative use and waste.

First of all, we should be careful in reporting the total yearly consumption. Too often this is based upon plunger displacement without any correction for slippage. Where such allowance is made it would be well to report the method by which the actual net pumpage has been determined. This information would give to the figures a value which they do not now possess.

We now have the following standard form as recommended by this Association.

(1) Population { Total. On line of pipe. Supplied.

(2) Total consumption for year.

(3) Quantity passed through meters and per cent. of total.

(4) Total number of meters and per cent. of services metered.

(5) Average consumption daily. { Total. Per inhabitant. Per consumer. Per tap.

In order to bring the matter definitely before the Association, the following form which seems to represent the minimum requirements is suggested.

BUSINESS AND PUBLIC USE.

(1) Business and public use by meters.
(2) Business and public use, unmetered (estimated).
(3) Business and public use, per capita.

DOMESTIC USE.

First-class dwellings, hotels and apartment houses.
- Gallons metered to this class.
- Estimated population metered of this class.
- Per capita metered daily of this class.
- Estimated population of this class.
- Estimated use of entire city, metered and unmetered, of this class, based upon above rate shown by meters.

Middle-class dwellings.
- Gallons metered to this class.
- Estimated population metered of this class.
- Per capita metered daily of this class.
- Estimated population of this class.
- Estimated use of entire city of this class.

Lowest-class dwellings, with scanty plumbing.
- Gallons metered to this class.
- Estimated population metered of this class.
- Per capita metered daily of this class.
- Estimated population of this class.
- Estimated use of entire city of this class.

DISCUSSION.

Mr. Leonard Metcalf.* It seems to me that Mr. Cole's suggestion is a very good one indeed. It is so plainly true that it hardly needs anything to be said in favor of it. Of course there is a practical difficulty in gathering the statistics which he suggests, but in a system which is thoroughly metered it ought to be possible to do it, and it seems to me that the cost of obtaining the information is so small that it might well be incurred. It does seem to me that it might be advantageous for the Association to give consideration to that fact in the form of statistics which has been prepared for general use, so that we might at all events obtain such additional information along these lines as is possible.

Mr. Elbert E. Lochridge.† Mr. President, I have been very much interested in Mr. Cole's paper, especially in the part re-

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* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

† Chief Engineer, Water Department, Springfield, Mass.

lating to business uses of water. I think, as Mr. Cole does, that one city can hardly be judged in comparison with another as to the use of water, for we may have a city which is well metered with a comparatively high consumption per capita, and another, with perhaps not more than forty per cent. of that amount. If we were able to designate, as of course is possible in some systems, what the water could be used for, we would largely eliminate some of the business uses, or at least show what these uses were and what they amounted to as a business proposition.

Mr. George A. Stacy.* I think Mr. Cole has opened up a new line of thought, or, rather, he has expressed the thought in a way in which it has not been expressed here before, which is of considerable value. It seems to me that there is a great lack of information in regard to it. It seems perfectly natural and perfectly right, if we are going to state the consumption per consumer, to state it as nearly correctly as possible. That is very difficult to do when we mix up other uses with the domestic use, as we have done in the past. It seems to me that this will be a long road to travel, if we are going to see it through.

The President. I think you might find it interesting to study the water consumption in the two cities of New Bedford and Fall River. They are very similar in the character of their population, both being cotton mill cities. In Fall River they have an abundant supply of water for their boilers, and do not use the city water. In New Bedford I think nearly all the water for condensing purposes is taken from the city mains, and, of course, the consumption per capita in New Bedford is from two to three times what it is in Fall River. The reason that is generally given to account for that is that Fall River is a metered city and New Bedford is not, but I think that is not the true explanation.

Mr. George A. Carpenter.† Mr. Cole has alluded in a modest way to a fact which is of much greater importance than he has given to it. We are in the habit of reporting our conclusions regarding the work of our pumping stations to a considerable degree of minuteness. We estimate carefully the amount of coal consumed, the amount of money expended in various ways, and then

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* Superintendent Water Works, Marlboro, Mass.

† City Engineer, Pawtucket, R. I.

as a basis for deciding upon the effective work of our systems we depend upon an altogether unknown quantity, the amount of water sent out by our pumps. We take for that factor the plunger displacement with, perhaps, a suggested amount of slip, amounting to something like 3 or 4 per cent.; because the engineer hardly cares to admit that his pump is giving an excessive amount of slip.

Now, I know that operating engineers will take exception to this statement, but I firmly believe, from what information I have been able to gather, that the amount of slip in a large majority of pumps in our pumping stations is an entirely unknown quantity; and yet we base all our calculations upon that quantity.

In an investigation made a few years ago, in regard to the consumption in a city which was rated by plunger displacement at about ninety gallons per capita, — not a large per capita consumption for our American cities, — I made a complete investigation, taking as a basis of the population the census returns of the enumerators at Washington, which divide a city into smaller districts than can usually be obtained from the reported returns, and taking for the water consumption of those same districts the meter records of the department. In this city where the consumption by plunger displacement and by the figures reported was upwards of 90 gal. per capita, the domestic consumption, when applied to purely domestic uses, was not over 20 gal. per capita, and the total metered consumption where factories and domestic consumers were both metered, was only about 40 gal. per capita. I am positive that the remaining 50 per cent. cannot in any way be accounted for by leaks or waste. In confirmation of that, a large section of this city was later supplied with a meter on the 12-in. main delivering water to that section, and the consumption was found to be practically what had been computed for it, without any addition of 40 or 50 per cent. for waste. It therefore seems to me decidedly important to measure the water as it goes from our pumps by some form of meter, for then we will have a better foundation upon which to base our future calculations.

Mr. Frank C. Kimball.* I had occasion to look into a plant this summer, where the superintendent instead of using the

* Civil Engineer, Boston, Mass.

plunger displacement to calculate the quantity of water which was pumped, shut the inlet gate into the pump well about once a month and pumped a given number of revolutions, and, noting the depth to which he drew the water, figured his plunger displacement from that, until he again tested it.

There were three pumps in that plant, and one of those pumps showed about 6 per cent., while one of the others showed something like 18 per cent. discrepancy between the actual pumpage as calculated from the well displacement and the plunger displacement. For some years now he has used that method, and does not enter his record as so much displacement less per cent. of slip, but enters it direct by dividing the displacement in his well by the number of revolutions. Wherever pumping is done from a well or a gallery, where the water can be shut off even for a limited time, say five minutes, this method will give you a very much better result than mere plunger displacement.

I can remember that the first time I had to calculate the discharge of a pump I was told to use 2 per cent. for the slip, as that would cover everything. I took occasion on that same plant, a little while later, to shut down the discharge gate, and pumped against it to see how many revolutions I could get out of the pump. Of course that is not an accurate method of determining the slip, by any means, but it is very much better than to assume 2 per cent., especially as I got about 7.5 per cent. out of that pump in that way.

Mr. Johnson. I can offer some further testimony, perhaps, on the line suggested by Mr. Carpenter. This last summer I have had occasion to try to reconcile the meter readings, where a meter was placed on a force main, with the records of the displacement of the pump. I was very much surprised to find that the meter would sometimes record 30 per cent. less than the pump for a period, say, of several weeks, then it would be practically the same and then, perhaps, for two or three weeks it would be 20 per cent. less than the plunger displacement. We finally notified the makers of the meter and had them send a man up to find what was the trouble with it. He failed to find any trouble with the meter, and then I sent a man out to study the pump records day by day. He stayed in the pumping station watching the meter and the counter, and as a

result we found that the trouble was entirely in the pump. We now, after having made some changes in the pump, have the readings practically in agreement, — perhaps one or two per cent. difference. Sometimes there would be a chip under one of the valves of the pump, and sometimes something else would happen, but in every case where there was a great difference there was something the matter with the pump. I was impressed with the fact very forcibly that it was not only essential to test the pump occasionally, but that it is decidedly essential to have a meter on the force main, in order to get any accurate results, — anyway with this kind of pump. This is not intended as an advertisement for meters, but I firmly believe that a meter is an excellent thing in my own pumping station.

Mr. Allen Hazen.* I have tried the experiment which Mr. Kimball described of closing the outlet of the pump and seeing how fast it would go, frequently; and I have almost always learned something from the experiment. In one case I remember a pump driven by water power which had been in use a good many years, and which was the main stand-by of a high-service system. Other pumps had been put in to help it out from time to time, but this old pump was the main stand-by. We needed to know how much water was being used, so one day I took the responsibility of closing the valve on the outlet. The pump never hesitated.

Mr. Robert S. Weston.† I was in Cincinnati a few years ago, and they told me a story about the old pumping station there which may be of interest in this connection. They had three very old pumps at the time the pumping station was dismantled, and on one occasion they stopped one of these three pumps, and no water ran into the reservoir with the other two pumps working.

Mr. John C. Chase.‡ I may add a word of testimony as to the testing of a pump for slip. Some fifteen or twenty experiments, carried on over a period of about six months, showed that only from 83 to 90 per cent. of the measured capacity of the pumps was obtained. The 90 per cent. was when a new plunger had been put in and it was in first-class condition. Our experience in pump-

* Civil Engineer, New York City.

† Sanitary Expert, Boston, Mass.

‡ Consulting Engineer, Derry Village, N. H.

ing against closed valves was practically the same as that of Mr. Kimball and Mr. Hazen.

Mr. W. F. Sullivan.* In Nashua we are separating the amount of water used by large manufacturing corporations and railroads from the rest of the consumption, and we find that it represents about forty gallons per capita out of the total.

Mr. Samuel A. Agnew.† A number of years ago I wrote a paper on what my pumps were doing at Scituate,‡ and I estimated that a certain amount of water was being pumped, subtracting 5 per cent. for slip. Since then I have had occasion to question the amount that I gave. In the summer there is a time when we use a great deal of water in the town, and I find I am not pumping as much water as I seem to in winter. I was wondering whether I could get any information as to the ratio between the vacuum and the amount of water a pump will deliver. I can shut up the gate on the suction and secure 28 in.of vacuum. I can open that gate in the middle of the summer, and I can make 26 in. That is the amount of vacuum I work against. I was wondering whether I could get any information as to the ratio of the amount of water pumped to the amount of vacuum. Possibly somebody can tell me. For instance, we have one pump which will deliver 160 gal. per minute at about 15 in. of vacuum, and I was wondering how much that pump would deliver at 26 in.

Mr. Hayes.§ What is your source of supply?

Mr. Agnew. Driven wells, 2.5 in. in diameter.

Mr. Hayes. What is the difference in their depth?

Mr. Agnew. I don't know anything about the depth of them. It would be the same if we had an open well, if we had 26 in. of vacuum. I was wondering how much water these pumps would deliver under 26 in. of vacuum.

Mr. Hayes. I can't answer the question offhand, but I do know of an experience they had over in Somerville, at the New England Dressed Meat and Wool Company. They put in 118 wells some 2 and some $2\frac{1}{2}$-in. and with them all on we could not get as much water as we did after we cut them down to 89. That

* Engineer and Superintendent, Pennichuck Water Works, Nashua, N. H.

† Superintendent of Water Works, North Scituate, Mass.

‡ Journal N. E. W. W. A., Vol. XX, p. 330.

§ F. H. Hayes Machinery Company.

is to say, we got better vacuum with the 89 than we did with the 118 from the fact that we were getting air. But to answer Mr. Agnew's question direct, how much water a $2\frac{1}{2}$-in. driven well will give with 26 in. of vacuum, I cannot.

Mr. Agnew. I was not asking how much the individual well would deliver. We have 40 of those wells, and it stands to reason that the pump, no matter in what condition it is, will not deliver as much water under 26 in. of vacuum as it will under, say, 10 or 15 in. I know it will not deliver a drop with the suction gate shut, and then I can make but 28 in. Now, there is 2 in. leeway. It is sometimes almost terrifying to go into the pumping station while the pump is working under those conditions. It is impossible to keep bearings tight enough so but what they will bang and rattle, and yet have them loose enough so they will not heat.

Mr. Hayes. You probably don't get solid water, but get some air. Do you take your calculations from your revolution counter against the water you pump?

Mr. Agnew. I did that once; I don't do it now.

WATER HAMMER.

TOPICAL DISCUSSION.

[November 9, 1910.]

MR. E. E. LOCHRIDGE.* I want to bring up for discussion the question of the use of water in direct pressure elevators where large amounts are used and paid for under the regular rates. Any water which is shut off quickly will develop a water ram, which will undoubtedly have some effect on the stability of the pipe. I do not believe that most of us realize how enormous a water ram can be. We ordinarily think of adding, perhaps, 50 per cent., or in some cases 100 per cent., to the pressure which we are working under, for the water ram. Recent studies have led me to believe that water ram can be considerably greater than that. This is a point to be taken into consideration in determining the thickness of the larger pipes in our distribution system.

The use of water elevators I know is allowed in some cities and is not allowed in others. It is getting to be an important question with us in Springfield, and I would like to get the ideas of different superintendents and engineers here on the subject, together with the experience which some of the cities have had with it, both those who have permitted the use and do not now, and those who now permit the use of water elevators and believe that it offers a good market for the water.

MR. JOHN H. FLYNN.† I think the best way to avoid the water hammer is to have such machinery as will not produce water hammer. If you let everybody put in elevators as they see fit, and run them as they see fit, you must expect to get water hammer. Water-works superintendents should not accept a water elevator system unless it is free from water hammer or any water troubles, and there is no trouble about getting such a system.

MR. WILLIAM F. SULLIVAN.‡ I will say that we have a great many railroad standpipes in Nashua, and every time a locomotive

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* Chief Engineer, Water Works, Springfield, Mass.

† Deputy Superintendent, Water Department, Boston, Mass.

‡ Engineer and Superintendent, Pennichuck Water Works, Nashua, N. H.

takes water we get what we call a great *jab* on our indicator card; and when there are four or five standpipes closed almost simultaneously, we get an extraordinary *jab*. We are trying to solve the difficulty, and have put it up to the railroad that they ought to erect tanks into which we could feed water, so that they could get these large quantities of water without danger of water hammer. The railroad people are around asking us to put in one of those large 4 000-gal. tanks in about a minute. I think the water ram or water hammer is going to be increased unless they have some other system than they have in the present standpipe arrangement.

With regard to elevators, we find the same trouble which Mr. Lochridge finds in Springfield; but we have meters on, and there are 4- or 6-in. pipes to them, and the water is taken direct and wasted into the sewer, and we get our money for it.

Mr. Walter H. Richards.* With respect to the elevator question and direct connected elevators, it occurs to me that possibly the water may be too valuable to be used in that way, particularly where there is a low or a moderate pressure, for with such a pressure of course they have to use a great deal of water. It seems to me, if the water rates are high enough and you put on meters, people would get tired of using the water before long, because the water is not applied in an economical manner, and its use would be too expensive.

Mr. George Cassell.† I have had a slight experience in regard to water ram in Chelsea, and I have been unable to find out from anybody whom I have approached what the cause of it was. Some months ago, through the interest taken by the insurance men, we put in a special high-service gravity system for sprinklers and no other purpose in the manufacturing establishments in the eastern section of the city, as the pressure we had up to this time did not satisfy them. When we had got it installed and in operation we found that the pressure at the end of the line in the eastern section of the city on the sprinkler system in a very large manufacturing concern was 108 lb. static pressure. A short time afterwards I had a telephone message from that company stating that the pressure was so great that it had started some

* Engineer Water Department, New London, Conn.

† Superintendent Water Works, Chelsea, Mass.

of the sprinkler heads, and they would like to know if we could not do something to reduce the pressure.

A short time ago they rang me up again, and they were very much excited. They said that again sprinkler heads had gone because the water had jumped from 108 to 130 lb. I told them that we had nothing to do with it; that if there was anything to cause water ram it must be on their premises. I later talked with the engineer of this company, who is responsible for the installation of the sprinkler system and of the fire system which is connected with it, and asked him if he had been able to find out what caused the ram. He said that he had not. Then I asked him what sort of sprinkler heads he had that went off at 130 lb., and he told me the names of the different sprinklers. I won't mention them, because I am not here to advertise any sprinkler heads, but I took the matter up in regard to the number of pounds pressure that a sprinkler head would stand, and I found out that it was so much greater than the pressure they had that I made up my mind that the sprinkler heads that went off were so antiquated that they had better change them; and they have changed them, and since then we haven't had any trouble. But I haven't as yet found out what caused the water ram.

Mr. Frank C. Kimball.* I would like to ask Mr. Cassell if there was a meter on the pipe that ran into that mill, — on the fire pipe.

Mr. Cassell. No, sir.

Mr. Kimball. Possibly if there was a meter on there, — I do not know the place, so this is entirely impersonal and only drawn out as the result of some experience I have had in other places, — the meter might have shown some draft of water about the time that this water ram occurred.

Mr. Cassell. I am going to answer Mr. Kimball's suggestion in the way it was put to me once: "Why, you don't doubt the honesty of a manufacturer, do you?"

Mr. Kimball. I never did in my life, but I have metered every fire service that I have had anything to do with running into a mill for the past ten years, and I find that from the income point of view it is the best thing to do.

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* Civil Engineer, Boston, Mass.

Mr. Cassell. I should be very glad to install meters, but, the moment you begin to talk about that, the first question asked is, How much is it going to cost? — and when you tell them, they throw up both hands. The consequence is that the powers that be seem to decide with the people as against the practical men, and consequently we are considered antiquated in not installing something which would protect the city, up to the present time. But I think if they continue to place the burden upon the water departments the water superintendents will have to take some summary measures to protect themselves from criticism in the future.

Mr. Lochridge. Are there any superintendents or engineers present representing systems which have a pressure sufficient to operate elevators directly, who have eliminated the use of water elevators, and if so, why? I would like to have them tell what their experience has been along that line. I believe one of the speakers has referred to an indirect system, — that is, where the elevator is raised hydraulically, but where the power does not come directly from the main. If the water is taken from the main, and enough taken to operate an elevator, when it is shut off there must be some water ram, in any system which could be devised.

Mr. Kimball. In one company I had at one time something like thirty or forty hydraulic elevators. The water hammer caused by those was such that by a recording gage we could never tell within forty or fifty pounds what the normal pressure on our pipes was. A large part of that we finally overcame by insisting on an adequate air chamber placed on the pipes to take off part of the shock. A little later we got rid of nearly all of these hydraulic elevators, simply because the Electric Light and Power Company came into the field and wanted the business and we found that we could not compete with them at ten cents per thousand gallons; so we got rid of all the elevators. We were glad later that we did. I think that except at a price fully as great as, if not greater than, the ordinary price for water you cannot afford to have elevators connected directly with your mains. You cannot tell what is happening. You may have a break and you will not know what caused it. It may be a mile or two away from an elevator. I have an idea that elevators have a good deal to do with breaks on mains, when they are directly connected.

Mr. John J. Kirkpatrick.* Mr. Lochridge is not the only one who has had trouble with water hammer. I think we have all had some. I want to state a little experience we had. We have one building eight stories in height on our main street that we furnish with water for elevator purposes direct to their piston during the day only, because at night they run a steam plant to light the building, and operate their pump from that. They have a little well or water gallery that they take the water from. Sometimes they are kind enough to close the valve between their elevator and our main, and sometimes they are not. We are very unfortunate in having the meter so placed that they have on one or two occasions blown the top off of it, when they had their pump going at 150 or 160 lb.

But those troubles are trifling compared with the troubles caused by the water hammer that we get from the American Street Car Sprinkling Company. There is a standpipe with a valve or gate that they draw from, within perhaps one thousand feet of where I live. I have a pressure gage at my house and sometimes it is amazing to watch the fluctuations of pressure. The normal pressure at my house is about fifty pounds, and I have seen it go at chain lightning speed up to one hundred and twenty. I wondered at first what caused it, but after I had run around the corner I found that our friends, the street-car sprinkler company, had been filling their tanks and pouring in about 3 800 gal. in two minutes.

Mr. Flynn. Over on Bay State Road there is a block of twenty houses. In eighteen of those houses there are elevators, and they have been in for twenty-five years, but I have never yet heard of a single complaint, either from the people who live on that side of the street or from those who live on the opposite side. We have only an 8-in. main on the street. It seems to me that if eighteen elevators can be put in twenty houses without causing any trouble, if other water-works superintendents will look after their elevators they will have no trouble.

Mr. George E. Winslow.† It is a good while ago that I was the superintendent of our works, and it was a good while ago that

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* Superintendent of Water Works, Holyoke, Mass.

† Waltham, Mass.

this work of which I am about to speak was done. They started putting elevators in Waltham, and I did not like the idea of their being operated by the valves which were ordinarily used, which would burst our cement pipe in about a week. So I recommended putting on a relief valve which would be as large as the tap or larger. On most of the elevators that were run with a 2-in. pipe, I would have a 2-in. relief valve, and have it set at ten pounds above the normal, so if the elevator were shut off quickly the pressure would escape through the relief.

I remember the case of one company which was going to put in an elevator, and I wanted to have a relief valve put on as usual, but they said there was no necessity for it as their valve was made in a V-shape, so that it will shut off the water gradually, so that it was impossible to create a water ram. Theoretically that was all right, but I had a relief valve put on nevertheless, and after that was put on I had them try it, stopping the elevator as quickly as possible. The relief valve opened all right, and the main pipe would have opened if it had not been for the relief valve.

When the Fitchburg Railroad did away with the pumping plant which supplied the locomotives with water, I was asked to connect up to their standpipes so that they could take water direct from our mains. I insisted on supplying them through 4-in. pipe from an 8-in. main, with a relief valve at least 3-in. in diameter as near the shut-off gate as possible. The railroad objected, but after waiting a year decided to comply with my conditions, and we made the connection. After this plant had been installed I went and saw its operation at the time the first locomotive was filled. The man shut off the gate at the ordinary rate that the railroad man does work of that kind, and the result was that the relief valve opened and ran for thirty seconds before it closed. That showed that there was a good deal of force or momentum to that water and it took quite a while for it to be overcome. We never have had a break in Waltham from the elevators or from the standpipes to my knowledge, and I was there for some years. The relief valve on the standpipe was set at ten pounds above the normal. I can see no other remedy, if you are going to have elevators or are going to close any valve suddenly, other than a relief valve.

Mr. Metcalf. It perhaps is worth while to call attention to the remarks of Mr. Flynn as showing the inapplicability of the Boston experience to Holyoke and Springfield conditions. It is merely indicative of the relative slowness of our motion here. If you have gone up in some of the Boston elevators you will find the explanation immediately.

Mr. Richards. At Springfield, as I understand, they have increased their pressure considerably, perhaps doubled the pressure, or something like that; but, as I understand, they use the same elevators they had before they increased the pressure, so that they are using an elevator pipe larger than is necessary; and they have increased the velocity of the water, of course, and hence they have increased the water ram. I would suggest that possibly that could be cured by closing the gate a little, or perhaps making the aperture that the water is supplied through a little smaller. I think very possibly that might remedy the difficulty.

THE USE OF WATER EJECTOR FOR TRANSPORTING SAND.

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INTRODUCTION.

This paper is the outgrowth of certain experiments made by the Bureau of Filtration of the city of Pittsburg, under the direction of the writers, to determine the most economical method of transporting and washing dirty sand from the filter beds. Similar work had been done elsewhere, and the experiments hereinafter recorded were designed to supplement the then available information.

A summary of the data obtained in connection with these experiments, with reference to the other filtration works in this country, is also given, and it is hoped that with this information available in convenient shape for discussion, others may be induced to give their experiences with similar apparatus, for the benefit of the profession and all people interested and to make the history complete.

HISTORICAL.

London, 1886.

To Mr. William B. Bryan, chief engineer of the East Water Works Company, of London, England, must be given the credit for the first use of the ejector for transporting sand from filters, about 1886. The history of his attempts is given in Transactions of the American Society of Civil Engineers, Vol. LIII. He mentions one experiment in which sand was transported 700 ft. and lifted 12 ft. He also describes the method then in use (1903), which was a development of the above-mentioned experiments and is described as follows: *

* Trans. Am. Soc. C. E., Vol. LIII, p. 266.

"The dirty sand, instead of having to be wheeled a long distance out of the beds, as formerly, is merely wheeled into a cast-iron hopper, the water is turned on, under pressure, and left on until the whole of the dirty sand in the bed has been lifted out. It passes into one end of the rotary machine, and is also washed in transit. A little hydraulic engine, fed by pure filtered water, turns the arm inside the longitudinal cylinder, and the exhaust water flows into the hopper at the opposite end from the dirty sand, consequently there is always a current of water meeting the sand passing through the washer. The dirty sand overflows at one end, and, as the sand gets cleaner, it meets the cleaner water. The elevator drops it into a small iron receptacle and a $\frac{3}{8}$-in. jet of water throws the clean sand into an adjoining bed, the latter operation involving no loss of water whatever.

"In the original experiments, an unforeseen difficulty was met in connection with the suction pipe. This pipe was made somewhat coned, with the widest end of the cone dipping into the dirty sand, and the flow of water was so smooth that the organic matter in the sand formed a slime on the surface to a considerable distance, and prevented its efficient operation. Therefore the suction pipe was taken off and a straight pipe put in with the water entering a T-piece at the bottom, with holes drilled through so that it should enter four ways at once and the water jostle itself in all directions in passing up the pipe. No trouble has been experienced during the last seventeen years."

London, 1892.

In *Engineering* (London) for 1892, Vol. LIII, p. 621, an apparatus for washing sand from filters is described, which is something like that commonly used to-day. It was developed by Messrs. Hunter, Frazier, and Goodman, and consisted of a series of nine cast-iron hoppers 2 ft. 4 in. square and 2 ft. 2 in. high, with an ejector in the bottom of the hopper. The hoppers were arranged in series, the discharge from the first delivering into the top of the second and so on. The nozzles used were $\frac{3}{8}$ in. and $\frac{1}{2}$ in., and 3 cu. yd. per hour, with 5 000 gal. of water per cubic yard of sand, was given as the capacity of the machine.

Lawrence, 1895 and 1898.

The city of Lawrence, Mass., used a machine for washing the sand from its filter plant, which was the forerunner of the present

accepted type of sand ejector. This was suggested to the late Mr. A. H. Salisbury, superintendent, by Mr. Allen Hazen, who had seen a similar piece of apparatus at Hamburg, Germany. It is described as follows: *

"The bowls of the machine are four in number and are light sweepcastings made at a local foundry. The sand drops to the bottom of each bowl or hopper and is caught by an inflowing horizontal jet and carried across and upward through a 3-in. pipe into the next bowl. The fitting at the bottom of the hopper is a standard 3-in. cross, with a plug in the bottom for the purpose of cleaning. Into a bushing in the inlet end of the cross is placed a $1\frac{1}{2}$ in. pipe, to the end of which is attached a removable chilled-steel nozzle made from a piece of hexagonal rod. The nozzles in use have $\frac{5}{16}$-in. jets, although other sizes have been tried. At the outlet of the cross there is screwed a special 3 by 2 in. reducer, the small end of which is placed within the cross and is of bell shape in order to readily receive the mingled water and sand. These special fittings, which wear out continually, are made as required at the shop of the water department."

"The washer was built and erected early in 1895, and was first used on June 17. The cost of the patterns, castings, piping, lumber, and labor on the machine was about $150, and that of the concrete pavements and drains about $240, while the labor account of the department for setting up, etc., was about $150, making a total cost of $540."

"In an endeavor to find a more economical way of getting the sand to these washers than the method then in use (i. e., wheelbarrow work), one of the writers experimented with different arrangements for transporting the sand, and, in a short time, devised the following method, which was adopted. A traveling hopper, mounted upon a light frame of piping and placed at will wherever dirty sand is dumped, is fed from a 2-in. pipe from the main supply. Sand thrown into the hopper is carried by the entering water into and through a connecting length of 3-in. pipe to the main washer, where it is raised about 5 ft. into the first hopper of the machine. The nozzle of the traveling hopper is $\frac{1}{2}$ in. in diameter. The 3-in. pipe line varies in length from time to time, and is made of running lengths of pipe connected in such lengths as are necessary for a distance."

"This method has been in use since July, 1898, and has never failed carrying the sand to the washer from the most distant point required, about 200 ft., which is the maximum distance tried up to the present time. It appears that the sand has not only been

* Trans. Am. Soc. C. E., Vol. XLVI, p. 293.

washed more thoroughly since using this apparatus, due probably to a more complete mixing and scouring in the pipe line, but, also, there has been no apparent increase in the amount of water used, and, moreover, there has been a material reduction in the cost per yard. The ordinary water pressure at the machine, with everything running, is 63 lb. and at the hopper 56 lb."

It will be noted that the jets were horizontal in these washers and ejectors, thus differing from the practice at Hamburg and London.

Poughkeepsie, 1897.

This method of transportation seems to have been used previously (1897) by Mr. Charles E. Fowler, at Poughkeepsie, N. Y., who had successfully lifted sand 30 ft. and transported it 630 ft. through 4-in. cast-iron pipe.*

Albany, 1897.

The filtration works for Albany, N. Y., were designed in 1897–8, and provided for a sand-washing machine somewhat similar to that then in use at Lawrence, but having vertical jets as at Hamburg and which is described and illustrated in Transactions of the American Society of Civil Engineers, Vol. XLIII, p. 272. It consisted of five cast-iron hoppers arranged with vertical ejectors. The sand passed through each of the hoppers in succession, receiving an increment of clean water in each one, and discharging the dirty water over a depressed lip in each hopper to a drain. As far as the writers know, this is the only use of vertical jets in this country. An ejector has been used here since 1900 for transporting sand from piles to washer with great success.

Students of sand filtration in considering the various elements of cost entering into the operation of filters, have been impressed with the advantages which the use of ejectors for carrying the dirty sand from filters to the washers offered, and in the discussion of this paper, several suggested improvements along this line were made, many of which have since been adopted.

* Trans. Am. Soc. C. E., Vol. LIII, p. 250.

Pittsburg, 1900.

Along the same line, we find that in the designs for the Pittsburg Filtration Works of 1899–1901, by Mr. Allen Hazen, provision was made for the use of movable ejector hoppers in the filters and a system of pressure piping, hose and discharge piping, for the purpose of discharging to washers and from these into elevated wooden bins, from which it would be withdrawn to resand the filters.

This system was described and illustrated in *Engineering News*, February 13, 1902.

Philadelphia, 1901.

The Philadelphia Filtration Works were also designed about this time, and they provided for transportation of the dirty sand by ejector hoppers.

Some experiments were made to determine the best proportions of the apparatus, and the installation was designed on the basis of the results obtained. The results of these experiments were published in Transactions of the American Society of Civil Engineers, Vol. LVII, p. 386, and the first apparatus used is described in *Engineering Record*, Vol. XLVIII, p. 426, for October 10, 1903. Two cuts in this article show the portable ejector and washer designed for the Belmont filters. This washer was stated to have a capacity of 6.7 cu. yd. of sand per hour and to use 1,610 gal. per cu. yd. of sand, at a pressure of 60 lb. per square inch. Some experiments also were made at the Spring Garden Testing Station with an ejector for carrying washed sand back to the filter, but this was found to be unsatisfactory for various reasons and was abandoned.

Washington, 1902.

The success which had been attained by the use of this method of transportation induced the designers of the Washington filter plant to give it careful consideration and to experiment with various combinations, in an endeavor to find the most efficient apparatus.

These experiments are described and illustrated in the Trans-

actions of the American Society of Civil Engineers, Vol. LVII, p. 340, and the sand-carrying system was based upon their results. The ejector and washer used are shown upon pages 337 and 339 of that article. A 3-in. line of hose about 100 ft. long carries the discharge from movable ejectors to a 4-in. wrought-iron line along the walls of the filter and thus to the sand washers in the court. A similar method was also adopted at the Milford, Mass., New Haven, Conn., Providence, R. I., Peading, Pa., and Pittsburg, Pa., filters (1901) and also at a number of the smaller plants throughout the country.

It was found to have a distinct advantage, in that the sand was cleaned during its passage through the pipe and thus the number of hoppers required at the washing machine was diminished, with a consequent saving of wash water. Thus at Washington two hoppers were used at the machine, while at Pittsburg only one was required. At Pittsburg and New Haven, the washer ejector also serves to carry the sand back to a filter which is being resanded. A similar but modified form has recently been used at Washington, providing also for distributing the sand in water on the filter surface.

Pittsburg Experiments, 1905–6.

In the design of the sand-handling system for the first 46 filters for Pittsburg, the results of the Philadelphia experiments were available, and it was planned to make some additional ones along the same lines. These were carried out in the winter of 1905–6, and are summarized in Table 1. The $\frac{3}{4}$-in. nozzle with $1\frac{3}{8}$-in. throat 8 in. long gave the best results for 3-in. pipe 350 ft. long, and the $\frac{7}{8}$-in. nozzle with $1\frac{3}{8}$-in. throat 12-in. long gave best results with the 4-in. pipe 600 ft. long. On the basis of the above, the throats for the plant were ordered, as shown in Fig. 2, marked "S." Some tests were also made with hose, both laying out in lines and wrapped about a reel about 6 ft. in diameter. It was found that for the ordinary lengths used in filters, the increase of friction was not material.

When the results of the Washington experiments were published and the good effects of enlarging the throat in a Venturi fashion were realized, a further series of tests were decided upon. At

this time, the use of rifled pipe for conveying oil was brought to our attention and the lessened frictional resistances encountered in this work seemed promising for mingled sand and water.

TABLE 1.

RESULTS OF SAND EJECTOR EXPERIMENTS.

1905–6.

A.—3-in. hose and 3-in. pipe.

Experiment Number.	Diam. of Nozzle.	Diam. of Throat.	Length of Throat.	Dist. between N. and T.	Pressures. Nozzle.	Pressures. Discharge.	Cu. Yd. Sand per Hour.	Gal. Water per Cu. Yd. Sand.	Per Cent. of Sand.	Remarks.
	In.	In.	In.	In.						
9	$\frac{3}{4}$	$1\frac{3}{8}$	15	$1\frac{3}{8}$	100	23	9.0	940	17.7	300 ft. of pipe plus 30 ft. of hose.
10	,,	,,	,,	$1\frac{3}{4}$	100	21	6.93	1 020	16.5	do
11	,,	,,	,,	,,	100	20	8.17	930	17.8	do
12	,,	,,	,,	,,	100	20	7.81	930	17.8	do
13	,,	,,	14	,,	100	23	10.0	1 050	16.1	do
14	,,	,,	,,	,,	100	23	10.91	910	18.1	do
15	,,	,,	12	,,	100	23	10.29	1 030	16.4	do
16	,,	,,	10	,,	100	23	10.29	940	17.7	do
17	,,	,,	8	,,	100	23	12.00	820	19.8	do
18	,,	,,	6	,,	100	23	10.91	870	18.8	do
19	,,	,,	5	,,	100	23	10.29	930	17.8	do
24	,,	,,	5	,,	100	23	10.91	940	17.7	do
20	,,	,,	4	,,	100	23	10.91	870	18.8	do
21	,,	,,	3	,,	100	21	10.29	980	17.1	do
22	,,	,,	2	,,	100	19	8.17	1 160	14.8	do
23	,,	,,	1	,,	100	19	7.13	1 240	14.0	do
25	,,	,,	14	,,	100	$27\frac{1}{2}$	6.31	1 340	13.1	600 ft. of pipe plus 30 ft. of hose.
26	,,	,,	,,	,,	100	28	6.80	1 390	12.7	do
27	,,	,,	12	,,	100	27	6.20	1 520	11.7	do
28	,,	,,	,,	,,	100	27	6.13	1 540	11.6	do
29	,,	,,	10	,,	100	25	5.71	1 770	10.2	do
30	,,	,,	8	,,	100	25	5.85	1 630	10.9	do
40	,,	$1\frac{1}{4}$	23	,,	70	21	4.13	1 890	9.6	do
39	,,	,,	,,	,,	80	23	4.92	1 680	10.7	do
38	,,	,,	,,	,,	90	26	5.63	1 485	12.0	do
36	,,	,,	,,	,,	100	27	7.20	1 300	13.4	do
41	,	,,	,,	,,	100	27	16.66	1 500	11.9	do
37	,,	,,	,,	,,	120	27	7.12	1 390	12.7	do
31	$\frac{7}{8}$	$1\frac{3}{8}$	10	,,	100	31	6.42	1 720	10.5	do
32	,,	,,	,,	,,	100	30	5.00	2 160	8.5	do
33	,,	,,	,,	,,	120	35	5.07	3 080	6.1	do
34	,,	$1\frac{1}{4}$	23	,,	100	30	6.31	1 700	10.6	do
35	,,	,,	,,	,,	120	35	6.00	1 830	9.3	do

TABLE 1.— *Continued.*

RESULTS OF SAND EJECTOR EXPERIMENTS.

1905–6.

B.— 3 in. hose and 4-in. pipe.

Experiment Number.	Diam. of Nozzle.	Diam. of Throat.	Length of Throat.	Dist. between N. and T.	Pressures. Nozzle.	Pressures. Discharge.	Cu. Yd. Sand per Hour.	Gal. Water per Cu. Yd. Sand.	Per Cent. of Sand.	Remarks.
	In.	In.	In.	In.						
42	1	$1\frac{3}{8}$	23	$1\frac{3}{4}$	97	30	10.90	1 510	11.8	516 ft. of pipe plus 30 ft. of hose.
43	,,	,,	,,	,,	97	30	11.80	1 470	12.0	do
44	,,	$1\frac{1}{2}$	10	,,	95	27	14.68	1 150	14.9	do
45	,,	,,	,,	,,	95	27	14.10	1 200	14.2	do
46	,,	,,	12	,,	95	25	9.00	1 770	10.2	do
47	,,	,,	5	,,	95	27	8.88	1 550	11.5	do
48	$\frac{7}{8}$	,,	10	,,	100	27	11.24	1 000	16.8	do
49	,,	,,	9	,,	100	25	12.00	980	17.1	do
50	,,	,,	8	,,	100	25	13.33	870	18.8	do
51	,,	,,	7	,,	100	25	12.40	750	22 2	do
52	,,	,,	6	,,	100	25	11.42	1 010	16.7	do
53	,,	,,	,,	,,	100	25	11.62	990	17.0	do
54	,,	,,	5	,,	100	25	9.10	1 280	13.6	do
55	,,	,,	4	,,	100	25	11.62	1 170	14.8	do
56	,,	,,	15	,,	100	25	12.83	980	17.1	do
57	,,	,,	13	,,	100	25	14.70	980	17.1	do
58	,,	,,	11	,,	100	25	14.80	1 000	16.8	do
59	,,	,,	9	,,	100	25	11.42	1 020	16.5	do
60	,,	,,	15	,,	90	25	11.06	1 500	11.9	do
61	,,	,,	13	,,	90	25	10.28	1 636	11.0	do
62	,,	,,	11	,,	90	25	10.91	1 540	11.6	do
63	,,	,,	9	,,	90	25	9.47	1 740	10.4	do

Therefore arrangements for making tests were made, the necessary apparatus secured, and a site, Brilliant Pumping Station, was selected, because of the water and sand being readily available. It is this set of experiments that this paper will present in detail.

Pittsburg Experiments, 1907–8.

The equipment consisted of the following apparatus arranged as shown on Fig. 1 and Plate I.

First. A standard cast-iron hopper and bottom used in sand washers at the filtration works. This is made in the form of a frustum of a pyramid; it is 5 ft. square on top and terminates in a

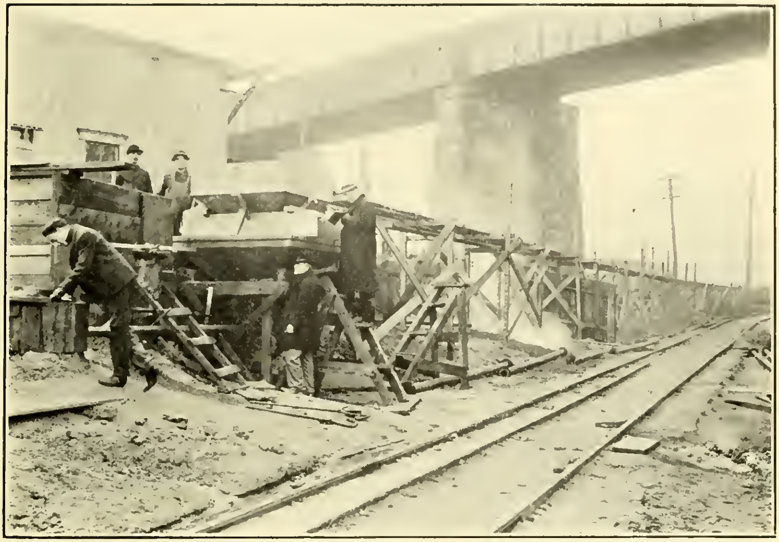

FIG. 1.

FIG. 2.

VIEWS OF EXPERIMENTAL SAND EJECTOR, AT BRILLIANT PUMPING STATION.

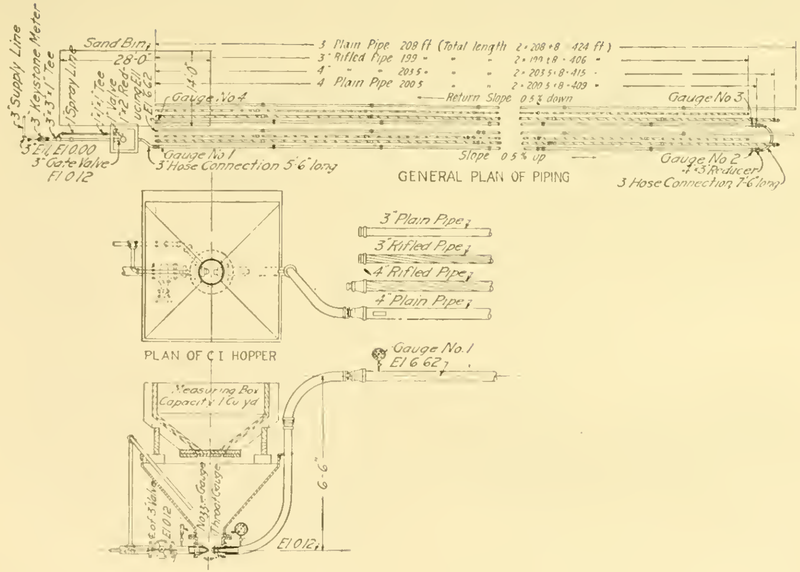

Fig. 1.

Sectional Elevation of Measuring Box and Cast-Iron Hopper.

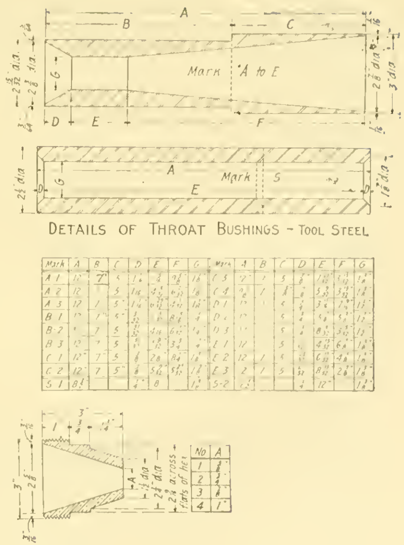

Fig. 2.

Details of Throat Bushings and Nozzles.

12-in. diameter opening, having a flange for attaching the bottom piece. The bottom piece has openings for the nozzle and throat pieces, an opening for a water jet, and a hand hole for adjusting the nozzle and throat.

Second. A set of 4 nozzles, having openings varying from $\frac{5}{8}$ in. to 1 in. These were made of brass.

Third. A set of 18 throats having various dimensions, as shown in Fig. 2; all made of tool steel.

Fourth. A measuring box of wood, carried by the hopper walls and provided with a slide in the bottom to drop the contents into the hopper. This box, when leveled off flush with the top, contained 1 cu. yd.

Fifth. A short piece of $3\frac{1}{8}$-in. internal diameter, flexible hose, provided with couplings on each end to connect with the pipe.

Sixth. Approximately 400 ft. each of 3-in. plain, 3-in. rifled, 4-in. plain, and 4-in. rifled pipe, as shown in Fig. 1. The rifled pipe was secured through the courtesy of Mr. Taylor Alderdice, vice-president of the National Tube Company, and Mr. J. B. Isaacs, consulting engineer, Union Pacific System, Southern Pacific Company, who is the patentee of the rifled pipe.

Seventh. Various gages for reading pressures and glass cylinders to observe transportation effect of mixed water and sand in pipe.

The water was supplied to the hopper from a 3-in. cast-iron pipe, connected directly to the force main from the station, and, after passing through a meter, its pressure was controlled by a 3-in. valve.

Sand was secured from a bin alongside the hopper and the ejected sand was returned to this bin, as shown. The water was drained off through the bottom and sides of the bin.

The pressure on the nozzle could be varied from 60 to 120 lb. by manipulating the 3-in. valve, and the pressures or heads at various points were determined by pressure gages, all carefully calibrated.

The effective size of sand was 0.24 mm., having a uniformity coefficient of 2.12.

The Venturi throats were made in three slopes, — 1 to 11, 1 to 8, and 1 to 4.6, designated as Nos. 1, 2, and 3, respectively; with various internal diameters, varying by $\frac{1}{8}$ in. from $1\frac{1}{8}$ in.

to $1\frac{5}{8}$ in. For the $1\frac{3}{8}$-in. diameter, No. 4 is identical with No. 3, except that the length of the reduced sections is shortened $2\frac{3}{8}$ in., which difference slightly increases the efficiency.

The wooden box was filled with sand leveled off and then, when the jet had been adjusted to give the desired pressure, a slide in the bottom of the box permitted the sand to be dropped into the hopper.

During the early experiments, no attempt was made to break up the arching of the sand which was always more or less troublesome and which gives results below the average to about the first two hundred experiments. About three hundred experiments, including the above two hundred, were run, using the lower spray, and regulating it so that the level of water remained constant in the hopper and about 15 in. below its top before any sand was dropped; this is designated as "Method A." Tests were then made without any spray whatever after the sand was started, one hundred gallons being estimated in each case for the fall of water in the hopper; this is designated as "Method B." The five hundred runs using this method form the bulk of the data from which conclusions can be drawn, but are all subject to some little uncertainty as to the exact amount of water used. After selecting the most efficient combination of apparatus a third method was used, viz., an open spray introduced from above was tried and still better results were obtained thereby; this is designated as "Method C."

Of these, 81 tests were run in order to obtain the frictional loss with water alone flowing in 3-in. and 4-in. pipe at various velocities; also, the relative efficiency of the Venturi-shaped throat and the throat of straight bore, under maximum efficiency conditions, as determined by previous experiments; and various comparisons of nozzle pressure and face-to-face distances, in order to complete certain curves for which data were lacking. The check runs were made, following the second method described above, except that the exact quantity of water used from the hopper was determined from measurements of height at the start and finish of the flow of sand. Since the early tests had shown that the hopper screen (needed in case of stones being in the sand, only), caused decided interference in the flow of sand, by aiding the arching; no screen was used during the later runs.

For the purpose of comparison, parallel sets of experiments were made on both plain and rifled pipe of 3-in. and 4-in. diameter. The plain pipe was of lap-welded steel in 20-ft. lengths, with cast-iron flanges and butt joints. The rifled pipe was made by the National Tube Company at McKeesport and was similar in design to the rifled pipe used in the transportation of crude oil in California.* The rolls indented the pipe $\frac{3}{32}$ in. and were at a pitch of 1.5 with the axis, making one complete turn in a distance of about

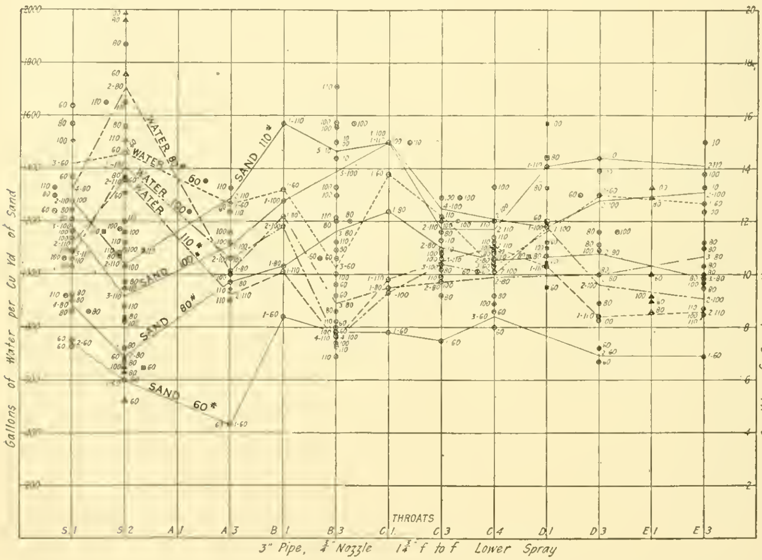

FIG. 3.
THROAT EFFICIENCY CURVE. (SEE NOTE ON FIG. 5.)

4 ft., and 5 ft. in the 3-in. and 4-in. pipes, respectively. It was thought that, by thus giving the mixture of sand and water a rotating movement, the sand would be better held in suspension, and trouble from stoppages, at low velocities, consequently diminished. As a matter of fact, however, the effect of the rifling was hardly noticeable, the full-bore glass cylinders, provided for observing the flow in the discharge line, indicating no perceptible whirl of the mixtures, even at velocities as high as 14 ft. per sec.

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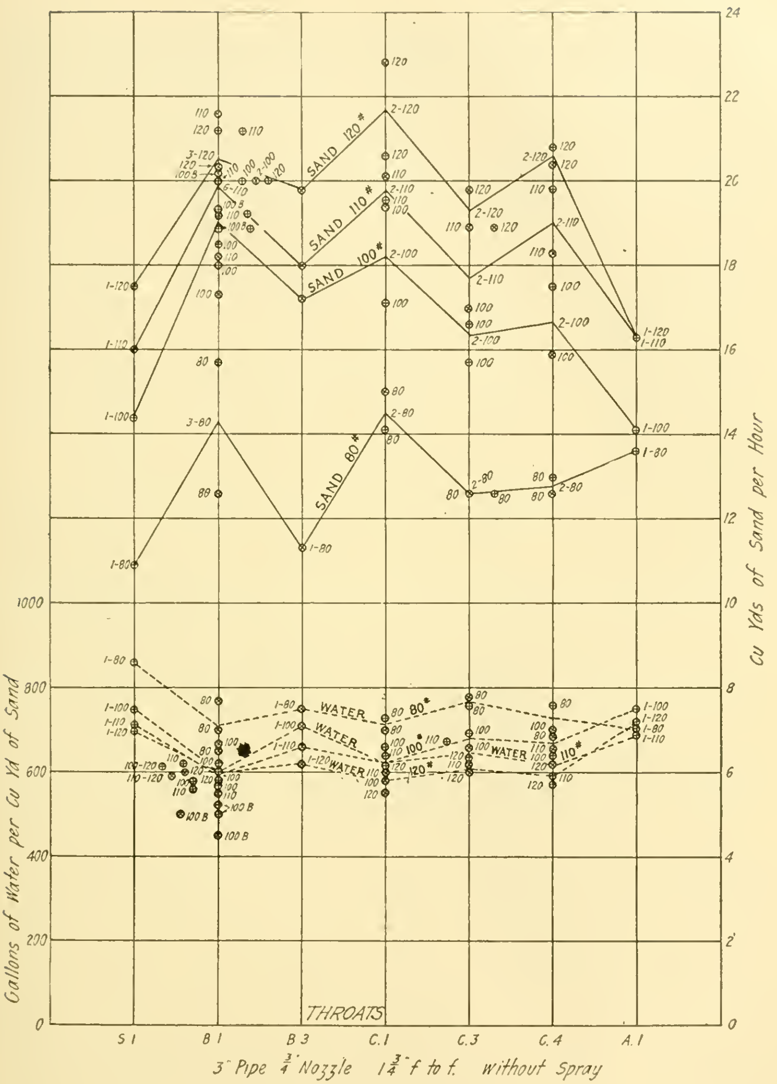
* See *Engineering News*, Vol. LV, p. 640.



THROAT EFFICIENCY CURVES
3" PIPE 3/4" NOZZLE

FIG. 4.

On account of the variable results which showed sometimes in favor of one, sometimes the other, both have been plotted and the mean values used in obtaining the average efficiency curves, except that for the friction diagrams the average curves have been drawn separately, and here slightly greater frictional loss is shown in the rifled pipe both for water alone flowing and for the various mixtures of sand and water. Considering the fluctuations of results this difference is too small to warrant a claim of material advantage for either the rifled or the plain pipe. Nine hundred and ninety-four runs were made in the period from November 21, 1907, to March 14, 1908, and about 10 per cent. of these have been eliminated on account of exceptionally high or low efficiencies which could not be duplicated. The remainder have been computed, tabulated, and the results are summarized in the following diagrams.

The results of typical tests on 3-in. pipe are given on Figs. 3 and 4, and show that the maximum efficiency is given by a $\frac{3}{4}$-in. nozzle, B-1 throat, $1\frac{1}{4}$-in. diameter, batter = 1 to 11, distance f. to f. = $1\frac{3}{4}$ in., nozzle pressure 100 lb. With this combination, an average of six runs gives a rate of 19 cu. yd. of sand transported per hour, using water at the rate of 600 gal. per cu. yd. By substituting C-1 throat, diameter = $1\frac{3}{8}$ in., approximately the same result is obtained, but with D-1 throat, $1\frac{1}{2}$-in. diameter, slightly less sand is carried per hour; showing that the efficiency is not diminished by wear, until the $1\frac{1}{4}$-in. throat is somewhat larger than $1\frac{3}{8}$ in.

For the 4-in. pipe, the typical results are given on Fig. 5, which shows the maximum efficiency is given by using a $\frac{7}{8}$-in. nozzle, D-1 throat, $1\frac{1}{2}$ in. diameter, batter = 1 to 11, distance f. to f. = 2-in., nozzle pressure 100 lb. With this combination, an average of four runs gives a rate of 31.4 cu. yd. of sand transported per hour, using water at rate of 460 gal per cu. yd. Throat E-1, $1\frac{5}{8}$ in. diameter, gives approximately the same results, showing that the efficiency is not diminished by wear until the diameter of throat is somewhat larger than $1\frac{5}{8}$ in. It is readily seen that the efficiency of the 4-in. pipe is relatively greater than the 3-in. pipe.

The enlargement of the throats by wear is quite marked, the maximum being an increase in diameter of $\frac{1}{4}$ in. for the 150 cu. yd.

of sand ejected, or 0.0017 in. for each cubic yard. It is evident that an attempt should be made to secure a more economical material or form for throats.

The economical distance from face of nozzle to face of the throats is in all cases $1\frac{3}{4}$ in. for 3-in. pipe and $\frac{3}{4}$-in. nozzle, and 2 in.

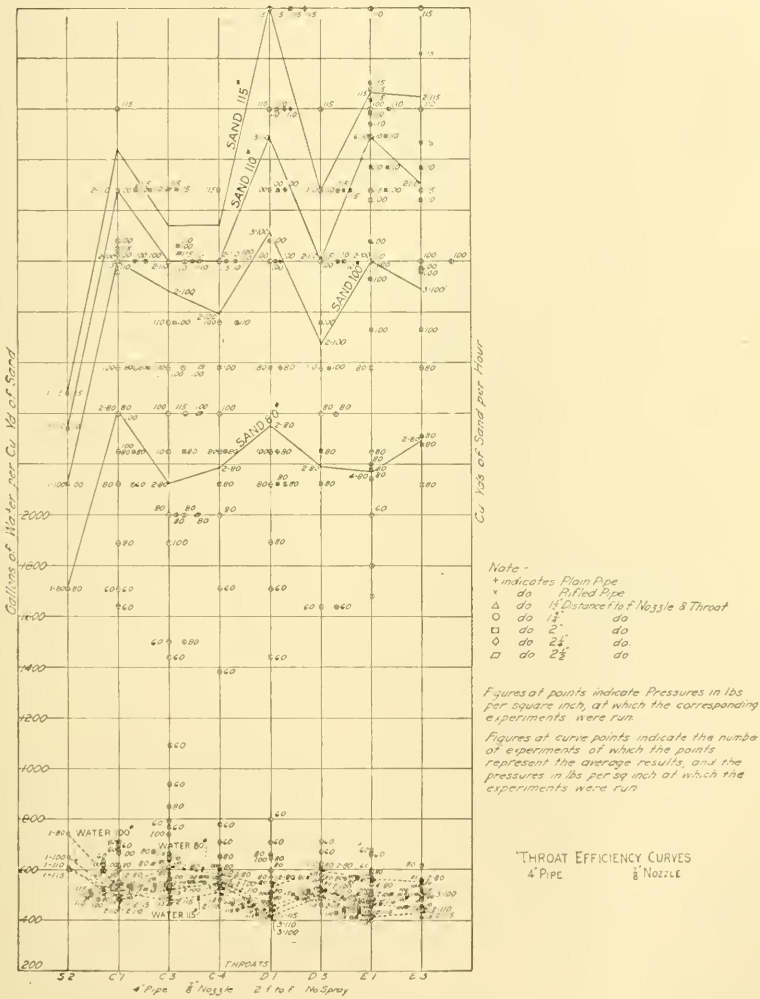


FIG. 5.

for 4-in. pipe and $\frac{7}{8}$-in. nozzle, and it is essential that the faces be centered with each other, that is, at equal distances from center line of hopper. One hundred pounds pressure at the nozzles is indicated as being the most economical; above this pressure the relative increase in efficiency is small, for the 3-in. pipe being almost a horizontal line after passing this point. Both of these statements are evident from the complete tables and diagrams, which have been placed on file in the Library of the Association.

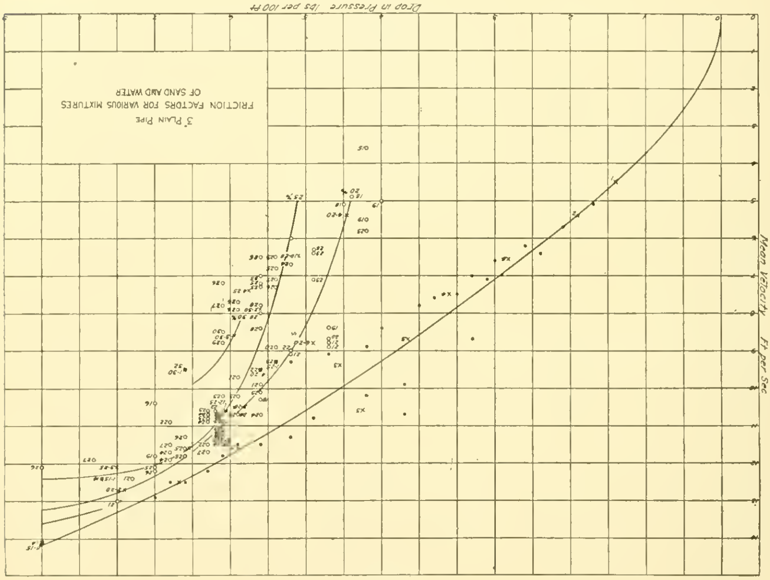


FIG. 6.

The straight throats, S-1 and S-2, were similar to those experimented with in 1905–6, and the maximum results were obtained with 100-lb. nozzle pressure, 750 gal. per cu. yd. and 14.4 cu. yd. per hour, or about 25 per cent. less efficient than the battered throat. These latter results, however, seem to exhibit greater efficiency than the earlier experiments.

The friction curves plotted on Figs. 6 to 9 show the drop in pressure per 100 ft. of pipe, for various percentages of sand and water and for water alone flowing. Since the curves were plotted

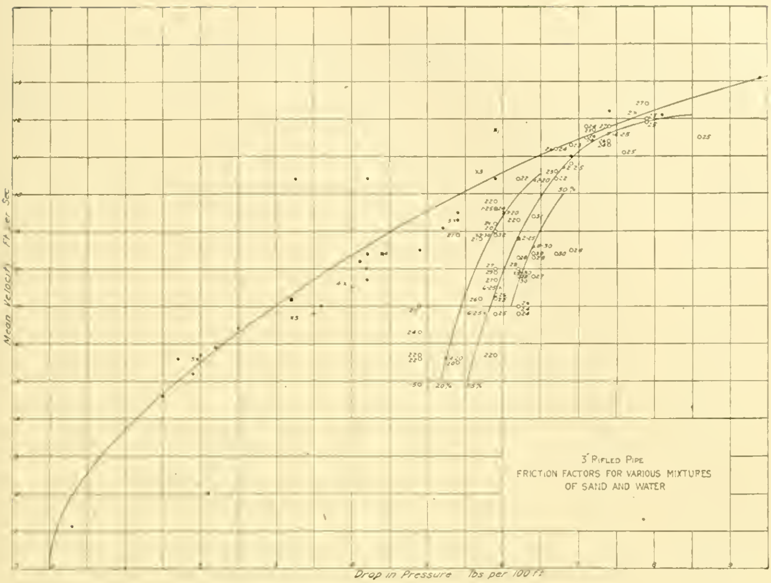

3" Rifled Pipe
Friction Factors for Various Mixtures of Sand and Water
Mean Velocity ft per Sec
Drop in Pressure lbs per 100 ft
20%
25%
30%

Fig. 7.

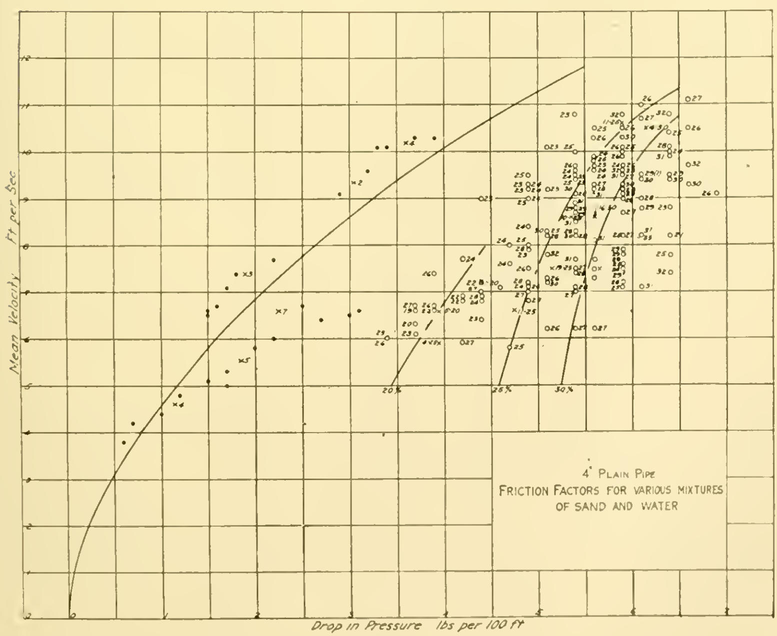

4" Plain Pipe
Friction Factors for Various Mixtures of Sand and Water
Mean Velocity ft per Sec
Drop in Pressure lbs per 100 ft
20%
25%
30%

Fig. 8.

from the drop in the total discharge line, without considering the rise of 0.55 ft. for the first 200 ft. and the equal fall for the return 200 ft. to the sand bin, they represent the values for horizontal pipe. For the 3-in. pipe and flow at 19 ft. per sec., the loss for a half per cent. upgrade is 14 per cent. greater and for a half per cent. downgrade is 14 per cent. less. The average loss of head at the 3-in., 180-degree hose bend, about 8 ft. long, is for 3-in. pipe

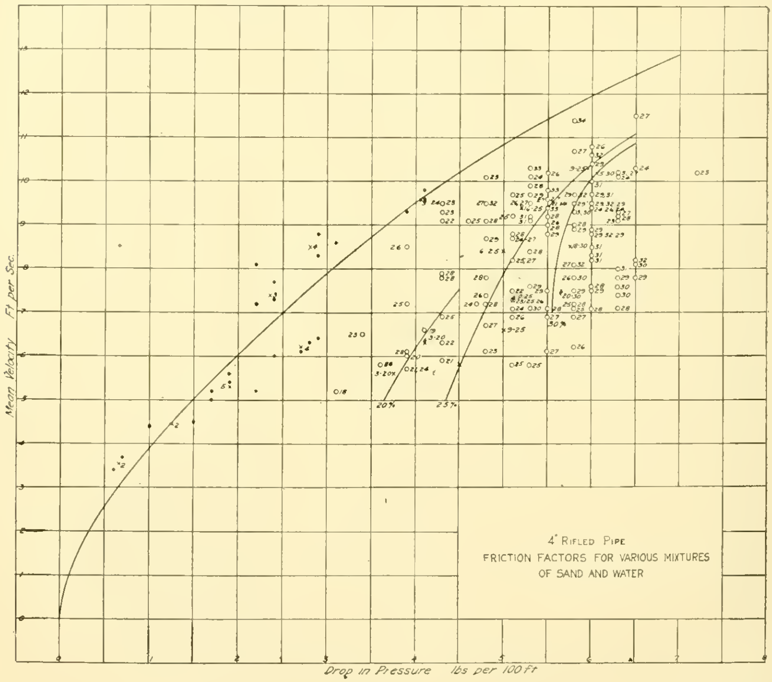


Fig. 9.

about 1 lb. and for 4-in. pipe about $2\frac{1}{2}$ lb., which shows the marked effect of the sudden contraction of section and increased velocity in the 3-in. hose when connecting 4-in. pipe.

The temperature observations upon the sand and water indicate a very slight advantage for the sand at the higher temperature, but the lessened efficiency is not well marked until the temperature

TABLE No. 2.

Results of Sand Ejector Experiments in 1907–8.

No. of Experiments.	Dia. of Nozzle.	Dist. F. of Nozzle to F. of Throat.	Throat Designation.	Discharge Line. Size.	Discharge Line. Length.	Time. Min.	Time. Sec.	Gallons of Water.	Method.	Gallons of Mixture per Minute.	Per Cent. of Sand.	Pressure. Noz.	Pressure. Dis. Line.	Sand in Cu. Yd. per Hr.	Mean Veloc. Ft. per Sec.	Drop in Pres. per 100 Ft.
	In.	In.														
88	3/4	1 3/4	B.1	3	424	7	20	1 310	A	206	13.4	60	18	8.2	9.0	3.5
89	3/4	1 3/4	B.1	3	424	5	50	1 220	A	244	14.2	80	22	10.3	10.6	5.2
86	3/4	1 3/4	B.1	3	424	4	40	1 180	A	297	14.6	100	27	12.8	12.9	6.4
87	3/4	1 3/4	B.1	3	424	3	50	1 010	A	317	16.7	110	31	15.7	13.8	7.3
90	5/8	1 3/4	B.1	3	424	8	40	1 100	A	150	15.5	60	13	6.9	6.5	3.1
91	5/8	1 3/4	B.1	3	424	6	50	1 070	A	186	15.9	80	15	8.8	8.1	3.5
92	5/8	1 3/4	B.1	3	424	4	00	670	A	218	23.2	100	25	15.0	9.5	5.9
180	5/8	1 3/4	B.1	3	424	10	00	970	A	117	17.2	60	15	6.0	5.1	3.5
181	5/8	1 3/4	B.1	3	424	6	50	810	A	148	20.0	80	18	8.8	6.4	4.2
182	5/8	1 3/4	B.1	3	424	5	30	700	A	164	22.4	100	18	10.9	7.1	4.2
184	5/8	1 3/4	B.1	3	424	5	00	760	A	192	21.0	110	20	12.0	8.4	4.7
220	5/8	1 3/4	B.1	3	424	11	20	1 080	A	113	15.8	60	18	5.3	4.9	4.2
222	5/8	1 3/4	B.1	3	424	6	40	890	A	164	18.5	80	22	9.0	7.1	4.7
218	5/8	1 3/4	B.1	3	424	6	10	1 000	A	195	16.8	100	24	9.7	8.5	5.7
219	5/8	1 3/4	B.1	3	424	5	20	770	A	182	20.8	100	22	11.2	7.9	5.2
223	5/8	1 3/4	B.1	3	424	4	30	700	A	200	22.4	110	25	13.3	8.7	5.9
342	7/8	1 3/4	D.1	4	409	3	30	610	C	260	22.2	60	18	17.1	6.5	....
343	7/8	1 3/4	D.1	4	409	3	10	550	C	269	23.7	80	18	18.9	6.8	4.4
344	7/8	1 3/4	D.1	4	409	2	50	560	C	305	23.5	80	17	21.2	7.7	4.2
345	7/8	1 3/4	D.1	4	409	2	40	550	C	319	23.7	100	19	22.5	8.0	4.7
442	7/8	2	D.1	4	409	2	20	410	C	306	28.4	80	23	25.8	7.7	5.6
443	7/8	2	D.1	4	409	1	50	370	C	367	30.1	100	24	32.8	9.2	5.9
444	7/8	2	D.1	4	409	1	40	340	C	385	31.5	110	27	36.0	9.7	6.6
456	7/8	2 1/4	D.1	4	409	2	40	470	C	290	26.2	80	23	22.5	7.3	5.6
457	7/8	2 1/4	D.1	4	409	1	50	370	C	367	30.1	100	27	32.8	9.3	6.6
458	7/8	2 1/4	D.1	4	409	1	40	350	C	391	31.0	110	26	36.0	9.9	6.4
459	7/8	2 1/4	D.1	4	409	1	30	340	C	428	31.5	115	26	40.0	10.8	6.4
514	1	2	D.1	4	409	2	11	530	C	382	24.3	80	23	27.5	9.6	5.6
515	1	2	D.1	4	409	2	04	510	C	393	24.9	90	23	28.9	9.9	5.6
516	1	2	D.1	4	409	1	58	510	C	413	24.9	100	26	30.4	10.4	6.4
611	3/4	1 3/4	D.1	4	409	3	07	460	C	244	26.5	80	22	19.1	6.2	5.4
612	3/4	1 3/4	D.1	4	409	2	20	350	C	280	31.0	100	25	25.8	7.0	6.1
613	3/4	1 3/4	D.1	4	409	2	10	340	C	296	31.5	110	26	27.7	7.4	6.4
614	3/4	1 3/4	D.1	4	409	1	55	320	C	324	32.5	120	25	31.3	8.2	6.1
620	3/4	1 3/4	B.1	3	424	3	15	510	C	25	24.9	100	28	18.5	10.9	6.6
621	3/4	1 3/4	B.1	3	424	3	00	500	C	267	25.2	110	30	20.0	11.6	7.1
622	3/4	1 3/4	B.1	3	424	2	50	480	C	277	25.8	120	38	21.2	12.0	9.0
670	5/8	1 3/4	B.1	3	424	6	30	570	C	134	23.2	80	20	9.2	5.8	4.7
671	5/8	1 3/4	B.1	3	424	4	35	450	C	164	26.9	100	25	13.1	7.1	5.9
672	5/8	1 3/4	B.1	3	424	4	08	440	C	180	27.3	110	28	14.5	7.8	6.6
673	5/8	1 3/4	B.1	3	424	3	25	370	C	196	30.1	120	28	17.5	8.5	6.6
674	5/8	1 3/4	B.1	3	424	2	56	340	C	219	31.5	130	30	20.5	9.5	7.1
788	3/4	1 3/4	B.1	3	424	3	20	520	C	247	24.6	100	28	18.0	10.7	6.6
789	3/4	1 3/4	B.1	3	424	3	00	470	C	257	26.2	100	28	20.0	11.2	6.6
790	3/4	1 3/4	B.1	3	424	3	00	510	C	271	24.9	119	30	20.0	11.8	7.1
819	3/4	1 3/4	B.1	3	424	3	05	490	A	225	29.2	100	28	19.5	9.8	6.6
820	3/4	1 3/4	B.1	3	424	3	14	520	A	224	28.0	100	28	18.6	9.7	6.6
821	3/4	1 3/4	B.1	3	424	3	07	500	B	225	28.8	100	28	19.3	9.8	6.6
822	3/4	1 3/4	B.1	3	424	3	10	520	B	228	28.0	100	28	18.9	9.9	6.6
835	3/4	1 3/4	B.1	3	424	2	50	460	C	268	26.5	110	29	21.2	11.6	6.8
836	3/4	1 3/4	B.1	3	424	3	07	520	C	264	24.6	110	28	19.2	11.5	6.6
837	3/4	1 3/4	B.1	3	424	3	02	520	A	238	28.0	110	30	19.8	10.4	7.1
838	3/4	1 3/4	B.1	3	424	3	00	480	A	223	29.7	110	30	20.0	9.7	7.1
839	3/4	1 3/4	B.1	3	424	4	00	700	B	226	22.4	110	30	15.0	9.8	7.1
840	3/4	1 3/4	B.1	3	424	2	58	490	B	233	29.2	110	30	20.2	10.1	7.1
841	3/4	1 3/4	B.1	3	424	2	57	480	B	231	29.6	110	29	20.3	10.0	6.8
842	3/4	1 3/4	B.1	3	424	5	00	900	..	180	.....	60	17	....	7.8	4.0
843	3/4	1 3/4	B.1	3	424	5	00	870	..	174	.....	55	16	....	7.6	3.8
844	3/4	1 3/4	B.1	3	424	5	00	860	..	172	.....	50	15	....	7.5	3.5
845	3/4	1 3/4	B.1	3	424	5	00	810	..	162	.....	45	14	....	7.0	3.3
846	3/4	1 3/4	B.1	3	424	5	00	770	..	154	.....	40	12	....	6.7	3.0
847	3/4	1 3/4	B.1	3	424	5	00	710	..	142	.....	35	11	....	6.2	2.6
848	3/4	1 3/4	B.1	3	424	5	00	670	..	132	.....	30	9	....	5.7	2.1
849	3/4	1 3/4	B.1	3	424	5	00	590	..	118	.....	25	7	....	5.1	1.6
850	3/4	1 3/4	B.1	3	424	5	00	510	..	102	.....	20	6	....	4.5	1.4
851	3/4	1 3/4	B.1	3	424	5	00	960	..	192	.....	65	19	....	8.4	4.5
852	3/4	1 3/4	B.1	3	424	5	00	1 020	..	204	.....	70	20	....	8.9	4.7
853	3/4	1 3/4	B.1	3	424	5	00	1 050	..	210	.....	75	22	....	9.1	5.2
888	5/8	1 3/4	B.1	3	424	4	29	430	C	163	27.6	100	23	13.4	7.1	5.4
889	5/8	1 3/4	B.1	3	424	5	27	510	C	149	24.9	100	26	11.0	6.5	6.1
890	5/8	1 3/4	B.1	3	424	5	15	520	A	138	28.0	100	25	11.4	6.0	5.9
891	5/8	1 3/4	B.1	3	424	5	37	570	A	137	26.2	100	25	10.7	6.0	5.9
892	5/8	1 3/4	B.1	3	421	5	17	530	B	139	27.6	100	25	11.4	6.0	5.9
893	5/8	1 3/4	B.1	3	424	6	03	620	B	136	24.6	100	25	9.9	5.9	5.9
895	5/8	1 3/4	B.1	3	424	5	05	520	B	142	28.0	100	25	11.8	6.2	5.9

TABLE No. 2.—*Continued.*

No. of Experiments.	Dia. of Nozzle.	Dist. F. of Nozzle to F. of Throat.	Throat Designation.	Discharge Line. Size.	Discharge Line. Length.	Time. Min.	Time. Sec.	Gallons of Water.	Method.	Gallons of Mixture per Minute.	Per Cent. of Sand.	Pressure. Noz.	Pressure. Dis. Line.	Sand in Cu. Yd. per Hr.	Mean Veloc. Ft. per Sec.	Drop in Pres. per 100 Ft.
	In.	In.														
896	$\frac{5}{8}$	$1\frac{3}{4}$	B.1	3	424	4	42	490	C	168	25.5	110	25	12.8	7.3	5.9
897	$\frac{5}{8}$	$1\frac{3}{4}$	B.1	3	424	4	58	520	C	167	24.6	110	26	12.5	7.3	6.1
898	$\frac{5}{8}$	$1\frac{3}{4}$	B.1	3	424	4	55	520	A	147	28.0	110	25	12.2	6.4	5.9
899	$\frac{5}{8}$	$1\frac{3}{4}$	B.1	3	424	4	55	520	A	147	28.0	110	25	12.2	6.4	5.9
900	$\frac{5}{8}$	$1\frac{3}{4}$	B.1	3	424	4	50	500	B	145	28.8	110	25	12.4	6.3	5.9
901	$\frac{5}{8}$	$1\frac{3}{4}$	B.1	3	424	5	12	550	B	145	26.9	110	25	11.5	6.3	5.9
903	$\frac{5}{8}$	$1\frac{3}{4}$	B.1	3	424	3	58	410	C	179	28.4	120	26	15.1	7.8	6.1
904	$\frac{5}{8}$	$1\frac{3}{4}$	B.1	3	424	4	06	440	A	157	31.5	120	25	14.6	6.8	5.9
905	$\frac{5}{8}$	$1\frac{3}{4}$	B.1	3	424	4	13	470	A	159	30.1	120	26	14.2	6.9	6.1
906	$\frac{5}{8}$	$1\frac{3}{4}$	B.1	3	424	3	55	420	B	159	32.5	120	25	15.3	6.9	5.9
907	$\frac{5}{8}$	$1\frac{3}{4}$	B.1	3	424	4	28	480	B	153	29.6	120	26	13.4	6.7	6.1
909	$\frac{5}{8}$	$1\frac{3}{4}$	B.1	3	424	16	00	1 010	C	82	15.4	25	20	3.8	3.6	4.7
911	$\frac{5}{8}$	$1\frac{3}{4}$	B.1	3	424	4	02	510	B	177	28.4	100	25	14.9	7.7	5.9
912	$\frac{5}{8}$	$1\frac{3}{4}$	B.1	3	424	4	20	510	B	164	28.4	110	25	13.9	7.1	5.9
913	$\frac{5}{8}$	$1\frac{3}{4}$	B.1	3	424	4	10	480	B	164	29.6	120	26	14.4	7.1	6.1

Explanatory Notes to Accompany Table 2.

Length of Discharge Line.

The length of discharge lines used for all computations was found by deducting from the total length of lines; first, length of $\frac{1}{4}$ bend, connecting line to hopper (7 ft.); second, length of hose connecting bend and line (6 ft.). Hence, for 3-in. Plain Pipe, L = 437 ft. — (7 + 6) = 424 ft.

Description of Methods.

A. The hopper was filled with water by the lower spray up to a convenient level, usually about 15 in. below the top of the hopper. Then the valve on the supply line was opened to the required nozzle pressure and at the same time the discharge of the lower spray was so adjusted as to keep the water in the hopper at its initial level; the flow of sand into the hopper was then started. At first this causes the water to rise; subsequently, as the sand was being drawn off, it began to drop. During this flow of sand from the hopper, the spray was shut off at such a time as to have the water at its initial level at the moment the last sand leaves the hopper. In practice, the approximate time for shutting off the spray was found to be the instant all of the one cubic yard of sand had left the feeding box.

The time required to discharge this cubic yard of sand into the hopper varied to quite a considerable extent, owing to two factors; first, the ability of the two men pushing the sand from the feeding box by means of flat sticks; second, the capacity of the different combinations of nozzles and throats to carry off the sand, as supplied. Using the $\frac{5}{8}$-in. nozzle, for instance, the sand was drawn off so slowly as to form a cone in the hopper, the apex of which shut off the feed opening completely for a time.

This difficulty of closely approximating the theoretical time for shutting off the spray is the cause of some error in the quantities of water used per cubic yard of sand, affecting all experiments run according to this method to a greater or less degree. For, when the final level is above the initial one, less water is used than gaged, more than gaged being used when the water closes below the initial level.

B. Same as method *A*, except that spraying water is introduced from above.

C. The hopper is completely filled by means of the spray, and the spray then shut off. Then the supply valve is opened to the required pressure, whereupon the water in the hopper begins to drop. As soon as it reaches a level of about 9 in. below the top of the hopper, the flow of sand is started into the hopper, causing the water to rise at first. As the sand is being drawn off faster than supplied, and more so after all the sand has entered the hopper, the water level drops and closes at from 12 in. to 28 in. below top of hopper. To determine the quantity of water used per cu. yd. of sand, 100 gal. is added to the amount gaged, as an allowance for the variable amount of water drawn from hopper.

For experiments Nos. 914–994, the initial and final levels are measured, and from these the corresponding quantities of water are computed.

Gallons of Mixture per Minute.

The sum of the water per cu. yd. in gallons, plus 1 cu. yd. of sand, reduced to gallons, = (202 gal.); divided by the time per cu. yd. of sand carried and expressed in minutes.

Per Cent. of Sand.

One cubic yard of sand in gallons = (202), divided by the sum of, 1 cu. yd. of sand in gallons (202) plus the amount of water in gallons used per cu. yd. of sand.

Nozzle Pressure.

This was read by a 4-in. pressure gage, placed on 3-in. supply line between valve and hopper. Care was taken to keep the pressure steady during the flow of sand, adjustments being necessary, especially when turning on and shutting off sprays, etc.

These explanatory notes are for the complete table, of which the above figures simply refer to nozzles B.1 and D.1, the complete table being on file in the library of the Association.

TABLE 3.

DATA FOR DIFFERENT SAND EJECTORS.

No.	Place and Year.		Hopper.	Nozzle.	Throat.	Spray.	Discharge Line.		Nozzle Pressure. Pounds.	Lift. Feet.	Mean Capacity. Yds. per Hour.		Per Cent. of Sand.
							Diam. Inches.	Lgth. Feet.			Av.	Max.	
1	London,	1892	2 ft. 4 in. x 2 ft. 2 in.	$\frac{1}{2}$ in. and $\frac{3}{8}$ in.	...	...	3 and 2	...	43	...	3	...	4
2	Albany,	1900	24 in. x 16 in. diam.	$\frac{7}{8}$ in.	$1\frac{1}{2}$ in.	1 in.	$2\frac{1}{2}$	100	40–50	10–12	10	12	8
3	Philadelphia,	1903	$26\frac{3}{4}$ in. x 21 in.	$\frac{3}{4}$ in.	$1\frac{3}{8}$ in.	$\frac{3}{4}$ in.	3	...	60	...	6.7	...	11
4	Philadelphia,	1903	$26\frac{3}{4}$ in. x 21 in.	$\frac{3}{8}$ in.	1 in.	$\frac{3}{4}$ in.	...	...	60	...	...	...	..
5	Washington,	1908	16 in. x 22 in. x 16 in.	$\frac{3}{4}$ in.	$1\frac{1}{2}$ in.	...	3	...	100	14	8	13	$6\frac{1}{2}$
6	Providence,	1908	....	$\frac{3}{4}$ in.	$1\frac{1}{4}$ in.	$\frac{3}{4}$ in.	4 (pipe) 3 (hose)	25 50	60	6	10	12	..
7	New Haven,	1908	3 ft. 0 in. x 20 in.	$\frac{3}{4}$ in.	$1\frac{3}{4}$ in.	...	3	150	38	12	6	...	$5\frac{1}{2}$
8	New Haven,	1908	....	$\frac{1}{2}$ in.	$1\frac{1}{4}$ in.	...	3	150	95	...	10	...	..
9	Reading,	1908	24 in. x 18 in.	$\frac{1}{2}$ in.	$1\frac{1}{2}$ in.	...	$2\frac{1}{2}$	100	70	8	36	...	20

drops below the freezing point, when the decrease is caused by the lumping of the sand.

Table 2 gives the details of the experiments with the combinations giving maximum results, being for throats B.1 and D.1.*

The results given above, together with the other published data, give an idea of the probable performance of ejectors under similar conditions which are close to the ideal. Such results cannot be hoped for in practice, but careful designing and operation will certainly prove economical in most cases on account of the lessened amount of water used.

Figures compiled from representative filter plants in 1908 are given in Table 3.

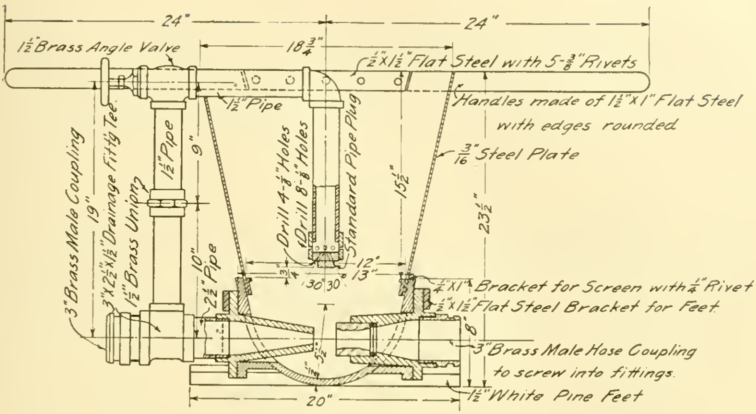
The portable ejectors and washers, designed for the Pittsburg works, are shown on Fig. 10, which also shows the design adopted for the washers for the last 10 filters constructed and shows how the results of the experiments were applied to the actual design. These washers have not been put in operation at this writing and the opportunity of comparing the actual results with experimental ones has not been given us. It will be noted that irrigators or jets, for breaking up the sand, are used in all designs; but these experiments lead us to conclude that while some form of spray is desirable to break up the arching of the sand, in the ejector this can preferably be introduced from the top. Furthermore, that the irrigator in the bottom is best for washers only, as the flow of water can thus be adjusted to displace the dirty water carrying the incoming sand and cause the dirty water to flow away over the top of the hopper.

CONCLUSIONS.

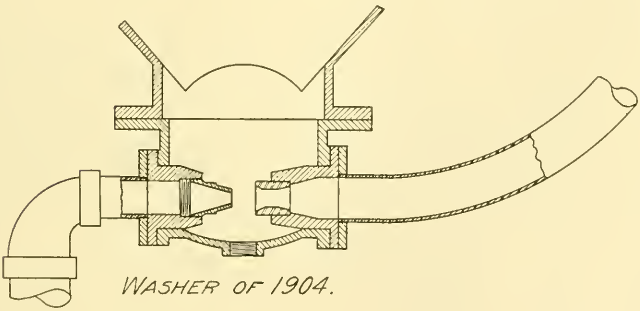
For any given installation there are a number of variables to consider, each of which has an effect, of greater or less moment, on the results. A typical design will call for, —

First. Determination of size of sand. The transporting power of the water depends upon the size of the particles, and the results given above would not apply to sand of greatly different effective size.

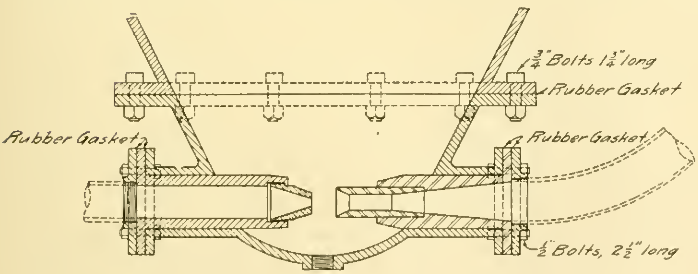
* Complete tables and diagrams of all results showing various other combinations have been placed on file in the Library of the Association, where persons interested may refer to them.



EJECTOR OF 1904.



WASHER OF 1904.



WASHER OF 1909.

FIG. 10.

Second. Determination of quantity to be handled per hour. This is governed by the number of men which it is convenient to use per ejector, in the case of hand scraping of filters, and may be taken as 10 cu. yd. per hour with three to four men. In the case of machine scraping, much greater quantities are possible, due to uniform feeding and larger ejectors.

Third. Determination of length of transportation. This is a very important feature and is one upon which experimental data are lacking. From the above results, however, friction losses may be obtained and thus the necessary pressure at head of the discharge main.

Fourth. Determination of available pressure at nozzle. The higher pressures give better results, but 100 lb. to 110 lb. per sq. in. may be taken as the limit, except in special cases where higher pressure is readily available.

With these data it will be possible to determine the size of nozzle and pipe and length of pipe possible, after determining upon the velocity required to transport the given material. The size of throat can also be approximated and easily determined after a few tests. For conditions similar to those obtaining during the experiments the selection of sizes is a comparatively easy matter, but where there are any considerable variations from these conditions, further experimental work may be necessary.

Fifth. These experiments and our studies show further that rifled pipe has no advantage over ordinary commercial pipe.

Sixth. That reasonable hose lengths not exceeding 200 ft. are no serious determent, if of smooth bore, lined with good rubber and without serious interruptions to flow due to irregularities at the couplings.

Seventh. The most efficient nozzle and throat combinations are $\frac{3}{4}$ in. with $1\frac{1}{4}$ in. and $\frac{7}{8}$ in. with $1\frac{1}{2}$ in.

Eighth. That, with these sizes and pressures of about 100 lb., the minimum velocity was about 5 ft. per sec. and this carried the sand without any tendency to deposit in the pipes.

Ninth. That, at this velocity, the loss of head is about 50 ft. per 1,000 ft. in length of pipe, which of course increases with the velocity, as shown on the diagrams.

In conclusion, it may be well to state that the scope of the experi-

ments was limited to the particular sizes given, on account of the necessity of adapting the throats and nozzles to the then existing hoppers and pipe connections.

DISCUSSION.

Chester F. Drake, Esq.* At Pittsburg portable ejectors are being used for the removal of the dirty sand from the filters to the washers in the galleries. Thence the sand is again ejected through the piping system to restoring machines placed in filters of low sand.

Believing that the practical features concerning durability and efficiency of the materials used will be of interest, we shall first state our experience along those lines.

The portable ejectors were made by E. M. Nichols, of Philadelphia. They consist of a cast-iron bowl surmounted by a sheet-iron petticoat.

The ejector nozzle is of hardened tool steel. The actual wearing part is $1\frac{3}{4}$ in. long, $1\frac{1}{4}$ in. outside diameter and $\frac{3}{4}$ in. bore.

The ejector throat is of chilled cast iron. It is about 7 in. long over all. The inner portion is a Venturi tube with the smallest diameter, $1\frac{3}{8}$ in. In a distance of 5 in. the diameter increases from $1\frac{3}{8}$ in. to $2\frac{1}{8}$ in. The bore of the throat is not finished, as such work is done by the sand passing through.

As stated by the author, we also found that a screen promoted arching and greatly decreased the quantity of sand handled. The laborers also found that the use of screens decreased their work, but a spray increased the output of sand very much.

The hose used for conveying the sand was 3-in. rubber hose; it was heavy and practically non-collapsible. The inner rubber tube has never yet shown signs of wear, in spite of the fact that the brass couplings and expansion rings wear rapidly.

The Pittsburg plant has a considerable amount of sand piping, of 3-in. and 4-in. wrought-iron pipe, with the outside coated by immersion in pipe dip. Dire disaster has been predicted for this pipe by several engineers of standing, but the pipes have been in use since December, 1907, having transported approximately

* Superintendent Pittsburg Filtration Works.

100 000 cu. yd. of sand to various parts of the plant, and we have yet to find one length of straight pipe which has shown appreciable wear, the only appearance of any wear being along the lower third of the inside surface. It is true that there has been some wear on the curve pipes near the sand washers in the galleries. In some instances we have substituted short lengths of hose for the curved pipes, with success, thus increasing the life of the equipment and decreasing the maintenance cost.

The sand lines carrying the sand from gallery to gallery are 4-in. wrought-iron pipe. The total length between galleries is approximately 565 ft. We have not experienced any more trouble in transporting sand through the long 4-in. line than we have experienced with the shorter 3-in. lines.

The nozzles of the sand washers are of brass. They are $3\frac{1}{4}$ in. long over all. The bore tapers from $2\frac{5}{8}$ in. diameter to $\frac{3}{4}$ in. diameter. Originally we brought the taper down to the front of the nozzle. This caused a fluting on the front face of the nozzle, producing a back lash which cut down the output of the hopper. It was therefore determined to run a $\frac{3}{4}$-in. bore for $\frac{1}{8}$ in. along the axis of the nozzle, after which the taper is carried out as in the previous nozzles. This has resulted in a considerably increased life of the nozzle as well as decreased clogging of the washers.

The water for sand washing, transporting, and restoring is obtained from two 5-million and one 3-million gallon D'Auria pumps which furnish wash water under 100-lb. pressure.

The dirty sand at Pittsburg is ejected, washed, transported to another bed, placed, and leveled, in one continuous process, without stops. Deducting all time for moving, placing, and removing hose and portable ejectors, the ejector handles 9.2 cu. yd. of sand per hour. Taking into account all time of moving, placing, and removing hose and portable ejectors, as well as the transfer of machines for restoring the sand, there are handled 6.9 cu. yd. of sand per ejector hour. During the first seven months of this year, we have ejected, washed, transported, and replaced approximately 40 000 cu. yd. of sand. In this work, we have used approximately 420 million gallons of settled water. It is estimated that this water costs \$11.41 per million gallons pumped. This cost is divided as follows:

Labor . . . . 70 per-cent.
Fuel . . . . 26 ,,
Supplies . . . . 4 ,,

It is evident, then, that the water for sand ejecting, washing, transporting, and restoring cost approximately $4 800.00, or 12 cents per cu. yd. of sand handled.

Concerning the amount of water used, we have found it advisable to run the water in the washers during the half hour of dinner. If we were drawing from a standpipe, we would undoubtedly not follow this custom. The starting and stopping of pumps takes some time, requiring the attendance of men at the washers. We found that the labor charge attending the stopping and starting overbalanced the cost of wash water in running straight through the day. We realize, however, the possibility of reducing the wash water about five per cent. by discontinuing this arrangement.

A series of analyses of wash water has been made to determine the bacterial content and turbidity of wash water after successive passages through washers. In the examination of the figures given below, it should be remembered that the sand is frequently passed through a washer in order to gain extra impetus in the transportation, rather than to receive a real washing. With this idea firmly in view, we offer the following:

AUGUST 16, 1910.

Washing No. 1.		Washing No. 2.		Washing No. 3.		Washing No. 4.		At Restorer.	
Bact.	Tur.	Bact.	Tur.	Bact.	Tur.	Bact.	Tur.	Bact.	Tur.
90 000	18 800	23 000	3 200	14 000	2 000	19 000	1 200	15 000	430

It is evident that the bacterial content of the settled water was approximately 15 000, and that two washings brought the bacterial content to normal.

MAY 3, 1910.

Washing No. 1.		Washing No. 2.		Washing No. 3.		Washing No. 7.	
Bact.	Tur.	Bact.	Tur.	Bact.	Tur.	Bact.	Tur.
500 000	28 700	150 000	3 200	45 000	800	19 000	100

May 10, 1910.

Washing No. 1.		Washing No. 2.		Washing No. 3.		At Restorer.	
Bact.	Tur.	Bact.	Tur.	Bact.	Tur.	Bact.	Tur.
720 000	31 500	230 000	4 000	65,000	1 100	25 000	800

We have made studies of the cleanliness of the washed sand restored to the beds. We find that 100 grams of sand shaken in one liter of distilled water produces a silica turbidity lying generally between 25 and 65 parts per million. Recent specifications for sand in new filters at Pittsburg allow a limiting turbidity of 200 parts per million under the same conditions.

Mr. M. F. Collins.* What was said in both the papers regarding the washing of sand is very interesting to me. Of course when we make a comparison with the old Lawrence filter, we cannot have the same figures that are obtained at covered filters. On our open filter the sand must be transported from the beds to the roadway; it is then forced by the ejector to the washing machines, which are at an elevation of about 14 ft. After being washed, the sand is returned to the filter beds in wheelbarrows, which is a slow and costly method.

At our covered filter we have kept careful notes on the cost of operation. In scraping the sand from the bed we put the ejector in the middle of the filter and transport the sand to the storage bin. This operation costs us about 29 cents a cubic yard. There are times in the summer when we can wash and return the sand for the same price, but this cannot always be done, since we only spread the sand on the filter once a year; consequently we have to store it.

On the open filter it is pretty hard to make any comparisons at all, because the boys are continually throwing stones on to the beds, so that we have to have a screen on the ejector to remove the stones during the operation of sand washing. But in the covered filter we get very good results, and on the level ground we have washed in a single day 48 cu. yd. of sand. Mr. Knowles speaks of

* Superintendent Water Works, Lawrence, Mass.

100-lb. pressure, but in Lawrence we are confined to about 63 lb., so I think that with the diminished pressure that we have, and the difficulties encountered in the open filter, such as I speak of we show very good results. I would say that, so far as our sand is concerned, we find, as Mr. Knowles contends, that the further we transport it through the pipe, the cleaner the sand is when it comes out, for the agitation received in passing through the pipes helps it to scour it.

Mr. Allen Hazen * (*by letter*). In the first Pittsburg design to which Mr. Knowles has referred, there is a pipe shown underneath the ejector, which was called the "irrigator." That pipe plays a somewhat important function in washing the sand which was not mentioned by Mr. Knowles. We have used the irrigator in all sand-washer designs since this first Pittsburg design.

In the earlier washers at Hamburg, Albany, etc., the sand was freed from dirty water by a process of dilution. Every time it went through the hopper some of the dirty water was separated and some clean water was mixed with it, and so the dirty water was diluted until finally a degree of dilution was reached where there was not too much dirt left. The function of the irrigator was to introduce clear water at the bottom in a special chamber of such size that the sand would settle down into it, and the clean water would be carried forward with the sand, while substantially all of the dirty water was displaced. With this arrangement there was a better separation of dirt in a single hopper than had previously been reached with several hoppers.

Mr. F. F. Longley, now resident engineer of the Toronto Filters, formerly at Washington, has made very numerous and painstaking investigations of the relations between the size of jet, the size of throat, the pressure of water supplied to the jet and the pressure of water obtained at the discharge, and the frictional resistance of mixtures of sand and water in piping. These investigations have extended through at least six years, including some preliminary experiments that I made at Washington. Many of these experiments have been written up for office use and many designs have been based upon them. I have thought that some time Mr. Longley and I would publish a description of this work, but it

* Consulting Engineer, New York City.

has been postponed because added data is being accumulated from time to time. A very concise statement of some of the leading results is presented in the American Civil Engineers' Pocket-Book, published by Wiley & Sons, pages 932–935.

In general, the Venturi-shaped throat yields considerable more pressure than the throats of shorter length and sharper pitch that were used in all the earlier sand washer designs, and ejectors of this type should be used in all cases where the highest efficiency is desirable. More recently, throats made of straight pieces of water pipe have been used. Under favorable conditions the pressures obtained with these come within ten per cent. of those reached with the Venturi throats; and where high efficiency is not important, this type of throat is convenient.

To take up dirty sand scraped from a filter, about one volume of water is required to break down one volume of sand, making a slush mixture having sixty per cent. of solid sand by volume and a specific gravity of 1.59. This is an average result, and is taken as the basis of calculation. In handling clean sand less water may be used and slush of a higher specific gravity obtained.

With an ejector taking up slush of this kind there is a definite relation between the percentage of sand in the mixture that can be thrown and the percentage of pressure that can be developed by the ejector. Thus, with 5 per cent. of solid sand in the discharge by volume and an ejector of good design, a pressure at the discharge of 50 per cent. of the jet pressure may be reached; with 10 per cent. sand, 37 per cent. of the pressure may be reached; and with 15 per cent. sand, 28 per cent. of the pressure, etc.

Generally speaking, the smaller per cent. of sand in the discharge, the further sand can be carried or the higher it can be lifted; but, on the other hand, more water is required to make it go. Practically speaking, for any given condition an equilibrium will be reached with full feed of slush to an ejector at which the per cent. of sand in the discharge water is as high as can be maintained with the conditions of discharge and elevation that actually exist. These conditions may be calculated with sufficient accuracy for all practical purposes by a few simple formulas based upon the results of the experiments above mentioned.

In the first place, a tabular statement of the conditions obtaining in good ejectors at approximately average efficiency is given. This is for ejectors of the best shape but somewhat worn and not quite in the best condition. With everything in the best condition the results will be better, while with much-worn throats the efficiency will fall off from the figures given.

Per Cent. of Sand in Water Thrown by Volume.	5	10	15	20	25	30
Specific gravity of mixture	1.05	1.10	1.15	1.20	1.25	1.30
Per cent. slush by volume	8.3	16.7	25.0	33.3	41.7	50.0
Per cent. nozzle water by volume	91.7	83.3	75.0	66.7	58.3	50.0
Weight of slush per part water from nozzle	0.15	0.32	0.53	0.80	1.14	1.59
Q = ratio total weight of discharge to weight of jet water	1.15	1.32	1.53	1.80	2.14	2.59
P = proportion of jet pressure developed in discharge	0.50	0.37	0.28	0.20	0.14	0.10
T = ratio of diameter of throat to diameter of jet	1.18	1.33	1.50	1.73	2.02	2.38
V = ratio of velocity in throat to velocity in jet	0.79	0.68	0.59	0.50	0.42	0.35

For water alone, $V = \frac{Q}{T^2}$.

For sand mixtures, $V = \frac{Q}{T^2 \text{ Sp. Grav.}}$.

The specific gravity of 10 per cent. sand is 1.10, etc., closely enough for this calculation.

For any given ejector the amount of pressure that can be developed added to the velocity through the throat in terms of velocity in the jet is approximately constant. In other words, with a given ejector you can have so much velocity or so much pressure, or corresponding proportions of each, but as you get more of one you get less of the other. With ejectors of the Venturi type, working with water alone, this may be expressed by the equation:

For water, $(P+V)T^{1.4}=1.75.$

When mixtures of sand and water are thrown, the law is the same, but the specific gravity of the mixture is greater, and the diameter of the throat must be reduced to give otherwise corresponding results. With the maximum percentages of sand that can be thrown in each case, the equation becomes:

For sand, $(P+V)T^{1 \cdot 6}=1.75$.

For general use, without refinements, the equation may be written:

In general, $(P+V)T^{1 \cdot 5}=1.65$.

This is more easily solved on an ordinary slide rule and the constant is taken a little lower to allow for falling off in efficiency under various conditions.

Following the nomenclature used above, T should be so selected that QV will equal 0.9. No very great falling off in efficiency will be found with values of T such that QV is between 0.8 and 1.0. Within this approximate range the pressure that may be developed varies inversely as the square of Q. Expressed as an equation:

$$PQ^2=0.65.$$

Again, the figure given as 0.65 is not quite a constant; 0.7 and even 0.75 are obtained in special experiments under favorable conditions, and 0.65 is what should reasonably be obtained under average working conditions with a good design and parts replaced before they are too much worn.

These equations are all approximate. They are not strictly consistent among themselves, but they do represent substantially the practical conditions that have been found in ejectors under conditions of actual use, and they serve to allow these conditions to be computed in advance with sufficient accuracy for all practical purposes.

Ejector parts are best made of common cast iron. We have made them experimentally of brass, bronze, steel, and of specially hardened materials, but no increased wear was obtained from any of these justifying the added expense. The simple cast-iron parts wear substantially as long as the case-hardened ones or those of any special material.

The friction of mixtures of sand and water in pipes may be estimated by computing the friction of water alone at the same velocity in the pipe and adding 3.5 ft. per thousand for each per cent. of sand in the mixture. With 6-in. or larger pipe only 2.5 ft. per thousand need be added, while for 2.5 in. hose 4.5 ft. per thousand are to be added.

Those figures are sufficiently close for velocities 5 ft. per second

and over. Between 3 and 5 ft. per second the frictions will somewhat exceed the amounts so computed, especially near the lower limit, and below 3 ft. per second sand and water mixtures will not flow steadily.

In calculating the yardage, per cent. of sand in the mixture, etc., use —

$$\text{Velocity ft. per sec.} = \frac{137.5 \times \text{cu. yd. sand per hour}}{\text{Per cent. sand in discharge} \times \text{diameter}^2}.$$

$$\text{Cubic yards per hour} = \frac{\text{Per cent. of sand} \times \text{velocity} \times \text{diameter}^2}{137.5}.$$

The frictional resistance of various quantities of sand and water in pipes of several sizes are shown in tabular form below.

	Per Cent of Sand in Discharge.					
Cubic Yards per Hour.	5	10	15	20	25	30
			$2\frac{1}{2}$-Inch Pipe or Hose.			
4	480	165	130			
6		310	180	160	170	
8		500	280	200	180	200
10			390	260	220	210
			3-Inch Pipe or Hose.			
6	420	142	108	128		
8		225	136	125		
10		320	180	142	142	170
12		430	240	170	154	160
14			300	205	175	170
16			380	250	200	182
			4-Inch Pipe.			
8	180	74	70			
10	280	97	77	87		
12		126	89	88		
14		160	102	92	102	
16		200	120	102	104	117
18			140	111	108	117
20			160	123	113	120
22			184	135	120	123
24			210	152	130	128

Cubic Yards per Hour.	5	10	15	20	25	30
		5-Inch Pipe.				
10	98	50	55			
15	195	75	62	71		
20	320	110	76	75	83	
25		160	94	84	88	
30		210	115	98	94	100
		6-Inch Pipe.				
20	140	56	51	62		
30		97	67	66	75	
40		150	92	76	78	86
50		210	122	95	86	90

Mr. Knowles finds that increase of pressure above one hundred pounds does not give corresponding increase in capacity. With a given ejector this is often true, because with the higher pressure more water passes through the jet, the discharge pipe is filled with jet water alone, and there is no room left to take up sand. In the same way, if the jet is made too large, less sand will be taken up than with a smaller jet. Other things being equal, the size of jet should always be reduced when the pressure is increased. If this is done, there will always be an increase in the distance that sand can be carried or in the height that it can be lifted with an increase in the pressure of the feed water and this increase in distance and height is substantially proportional to the increase in pressure. On the other hand, the wear and tear of the apparatus increases rapidly with high pressure, and for ordinary work one hundred pounds may be a reasonable limit.

Up to the time of the design of the Washington plant, the largest piping used in connection with sand washing or handling was three inches in diameter. I became satisfied that there would be advantages in the use of 4-in. pipe and it was used. Up to that time the largest quantity of sand that had been handled was five or six cubic yards per hour. With the larger pipe at Washington the quantity of sand handled at once jumped to 10 and even to 12 cu. yd. per hour. It would obviously be possible to use 5-in. pipe and increase the yardage, but it may be doubted whether the business about an ordinary filter plant will warrant this. For special purposes, five or six inches and even larger piping may be advantageous.

With 100 lb pressure and 4-in. piping and a 0.7 jet, 10 cu. yd. of sand per hour can be carried horizontally for about 600 ft. or lifted 40 ft.; or a proportional amount of both lift and carry may be obtained; 15 cu. yd. per hour can be carried horizontally 400 ft., or lifted 30 ft.; and 20 cu. yd. per hour can be carried horizontally 250 ft. or raised 22 ft.

Generally speaking, 50 ft. of 3-in. discharge hose from the movable ejector to the end of the 4-in. pipe has as much resistance as from 100 to 150 ft. of 4-in. pipe, so that as a practical proposition with the washer on the roof of a covered filter with 0.7 jet and 100 lb. water pressure, we have 15 ft. lift and 50 ft. 3-in. hose and about 350 ft. horizontal run in 4-in. pipe, as a practical limit, at which 10 cu. yd. per hour can be handled. With longer runs, smaller quantities, and with shorter runs larger quantities up to 15 cu. yd. per hour and more may be handled.

In making calculations, the most convenient procedure is to assume a certain number of cubic yards per hour and certain lengths of discharge piping and elevations, find out what the frictional resistance in these will be with various percentages of sand in the discharge, and then calculate what pressures of feed water will be required to produce these conditions. If the required pressure of feed water much exceeds that which is available, then the assumed conditions are too difficult and must be made easier. On the other hand, if it comes within the limit of pressure that is available, the desired results will be reached, and making the calculation for a series of percentages of sand in the discharge water, and then interpolating from the results, a very close approximate figure can be obtained for the largest per cent. of sand in the discharge water that will be carried; and conversely, for the smallest size of jet that will accomplish the desired results.

By following out these calculations systematically it will be possible to be quite certain in advance of securing the desired results and also of securing a design that will do it with as small a quantity of water as can be made to accomplish the purpose.

Mr. Francis F. Longley * (*by letter*). In connection with the operation of the slow sand filters at Washington, D. C., the writer had an opportunity, a few years ago, of studying certain

* Resident Engineer, Filtration Plant, Toronto, Ont.

problems relating to sand washing and handling. Investigations were made on the frictional resistance of sand and water in piping, and laws were determined for computing the loss of head in 3-in. and 4-in. pipe. The relations between the sizes of jet and throat of ejectors, the quantity of material that could be handled, the pressure of water at throat and jet, etc., were also studied, and the results are reviewed in the following discussion.

Friction of Sand and Water in Pipes. The equipment available for the study of the friction of mixtures of sand and water in pipes consisted of the 4-in. wrought-iron pipe of the sand washer system supported permanently along the side walls of the filters; the 3-in. flexible hose used to connect up the ejector box with the 4-in. wrought-iron pipe; the ejector box; a measuring box for sand; meters to be placed on the pipe or hose lines; the differential mercury gages, etc. The determination of the loss of head consisted simply in establishing a steady flow for various conditions and measuring accurately the pressure at two points some distance apart or the difference in pressure at these two points on the pipe line. The first experiments were carried out by the use of pressure gages located at two points on the line. These pressure gages had dials graduated to 30 lb. The least graduation of the dials was one pound and the least reading that could be depended upon, due to the lack of refinement of the gage, was probably one quarter pound. The maximum difference in pressure at the two points chosen for the gages was only about 12 lb., and the usual difference, of course, much less than that. The least reading of the gage, therefore, represented so large a percentage of the difference in pressure usually observed that the accuracy of the observation was not nearly what was desired. The need of some more refined method of measurement was therefore very soon demonstrated. A differential mercury gage was then rigged up, consisting of a long U-tube of glass attached by suitable connections to a ½-in. wrought-iron pressure pipe which was carried along the 3-in. hose or 4-in. pipe to the points on the pipe at which the difference in pressure was to be observed. Cocks for checking the oscillations which resulted from the continual variations in the conditions of flow in the pipes, especially at low velocities, and for blowing off the ½-in. pressure pipes and

clearing them of sand, were provided, and every precaution taken to make the readings consistent. The arrangement of the pressure piping, differential gage, etc., is shown in Fig. 11. The greatest care was used in the placing of the ½-in. pressure pipe and the differential mercury gage to avoid the trapping of air in high pockets of the pipe, as it was found that such accumulations of air affected the readings of the gage to a considerable degree.

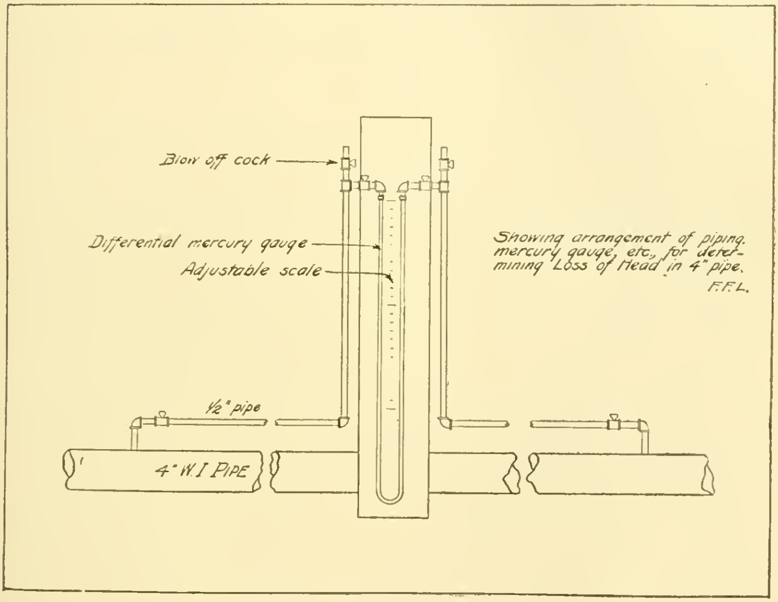


FIG. 11.

It was necessary to determine the following factors in this problem: The difference in pressure at two points a measured distance apart on the line under observation; the quantity of water passing through that section of hose or pipe, and the quantity of sand. One of the movable ejectors was hooked up in the usual way by means of two lines of 3-in. hose to the pressure pipe line along the wall. The water flowing through the section under observation could then most conveniently be measured in two parts, viz., the water supplied to the nozzle and the water sup-

plied to the irrigator. Two 3-in. meters were used for this purpose; one on the main supply to the nozzle of the ejector box and the other on another line of 3-in. hose supplying the irrigator. A separate line of hose to the irrigator is not needed, of course, in the regular operation of an ejector, but it was used here for convenience in the measurement of the water quantities. For the measurement of the sand flowing through the pipe or hose line under observation, a rectangular bottomless box holding just one cubic yard was used. This box was filled by shoveling the scraped sand into it until it was full and the top struck with a straight-edge and the box then lifted off. Piles of an even number of yards of sand were used for each run.

With all the apparatus placed ready for the experiments, the procedure for a single test run was somewhat as follows: The water was first turned on at the jet and at the irrigator and adjusted approximately to the velocity desired through the hose or pipe under observation, the supply of water to the irrigator being fixed so that the water level in the ejector box stood at a fixed depth of about 6-in. over the nozzle to insure complete submergence. When steady flow was established, the $\frac{1}{2}$-in. pressure pipe-lines were cleared of sand and air and filled with water by opening the cocks wide and discharging water through the blow-off cocks each side of the differential mercury gage. When this condition was perfected, the cock on each line nearest the point of attachment of the pressure line to the 4-in. pipe or 3-in. hose was partially closed until there was only a very small flow at the blow-off cock. The two blow-off cocks were then closed and the pressure communicated direct to the differential mercury gage and then the cocks on the pressure lines at each side of the differential mercury gage were gradually closed until the oscillations of the mercury column already referred to were reduced to a minimum.

The gage now being ready for observations, and the water flowing as already described at the jet and at the irrigator, the ejector box was filled with sand and the sand maintained at a constant level at the top of the box from an unmeasured waste pile of sand nearby. This process was continued for several minutes, if necessary, or until the flow of sand and water in the hose or pipe had reached a reasonably steady condition. The quantity of irrigator

water taken up when feeding sand to the ejector is of course much less than when the ejector is being supplied with water alone. The irrigator valve had then to be partially closed to adjust the quantity of water to give as perfect a condition of feed as possible at the ejector without causing the box to overflow. Then, at a definitely observed time, sand was supplied from one of the measured piles of sand instead of from the waste pile, and this procedure continued until an even number of yards of sand had been fed to the ejector. Finally, the time was observed when this even number of yards of sand had been exhausted and the sand in the ejector had run down once more to its initial position level with the top of the box. This fixed the time factor and the sand factor in the experiment. Readings were taken on the two water meters at the beginning and end of the run and also incidentally at intermediate times during the run in order to check up from time to time, if desirable, the uniformity of the supply. At the differential mercury gage-board readings were taken of the height of the mercury column at intervals of thirty seconds throughout the entire measurement period. The average of these was assumed as representing the difference in pressures at the two points of connection of the pressure pipe to the pipe or hose under observation

The results of these observations were then brought together, the percentage of sand in the mixtures determined, the velocity of the mixtures through the pipe or hose under observation determined, and the loss of head in feet per thousand feet computed from the observed readings of the differential mercury gage. These points were then plotted with loss of head per thousand feet as ordinates, velocity in feet per second as abscissæ, and the percentage of sand in the mixtures noted for each point so plotted. The problem then presented itself of determining from this data a suitable law of variation of the friction for different percentages of sand. A little study indicated that, for any given velocity which was great enough to keep the sand in suspension in the pipe, the increase in friction for equal increases in percentages of sand and slush was approximately constant. As an illustration of this, the points on the diagram corresponding to the ½-in. nozzle covered a very small range of velocities. A mean line was

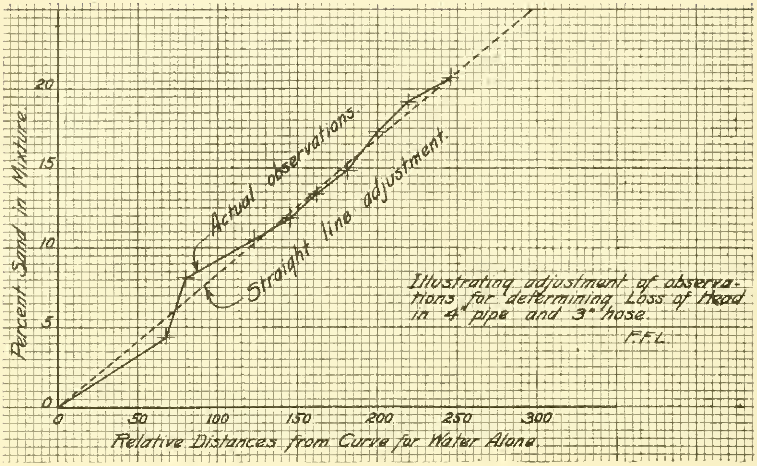

Percent Sand in Mixture.
0
5
10
15
20
0
50
100
150
200
250
300
Relative Distances from Curve for Water Alone.
Actual observations.
Straight line adjustment.
Illustrating adjustment of observations for determining Loss of Head in 4" pipe and 3" hose.
F.F.L.

FIG. 12.

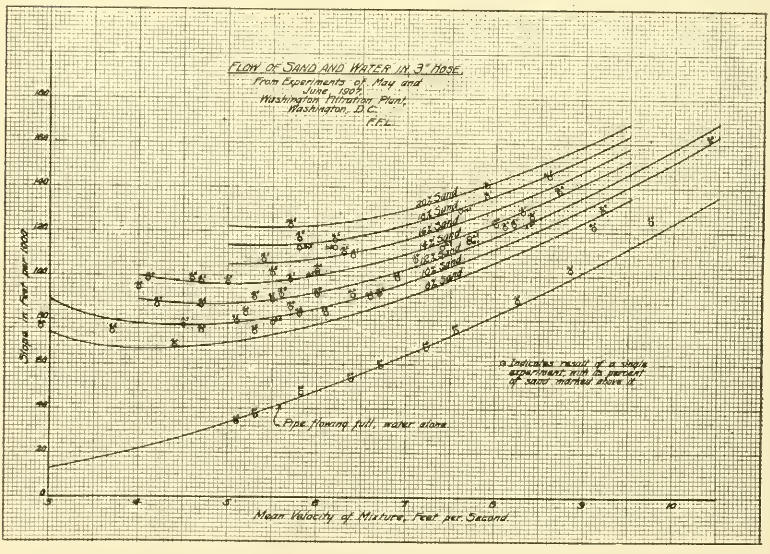

FLOW OF SAND AND WATER IN 3" HOSE.
From Experiments of May and June, 1907,
Washington Filtration Plant,
Washington, D.C.
F.F.L.
20% Sand
18% Sand
16% Sand
14% Sand
12% Sand
10% Sand
8% Sand
Slope in Feet per 1000
Pipe flowing full, water alone.
Indicates result of a single experiment, with its percent of sand marked above it.
Mean Velocity of Mixture, Feet per Second.

FIG. 13.

drawn through these points and the distance was measured along this line to the several points from the curve which had been carefully determined with the same equipment for the friction with water alone. It was found that these distances bore practically a constant ratio to the observed percentage of sand in the mixtures. This may be seen from Fig. 12, which is intended to illustrate this method of adjustment of observations.

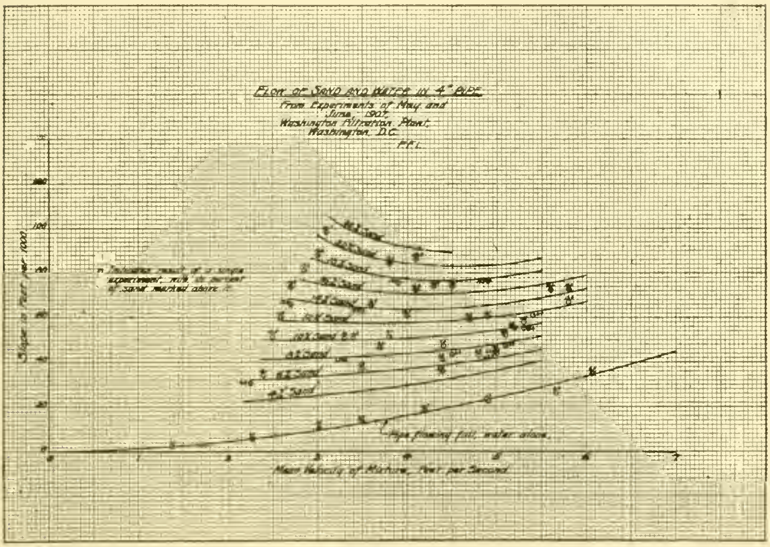


FIG. 14.

A study of other similarly related points showed that the same law applied very well, and consequently all the observations were classified according to small ranges of velocity. This method was applied for each set of figures and the points so determined used to plot curves. These curves are shown on Figs. 13 and 14, which mean substantially that the observations have been reduced to the basis of a factor to be multiplied by the percentage of the sand in the mixture and added to the friction for water alone for that velocity. These results may be stated in tabular form as follows:

Factor to be Multiplied by Per Cent. of Sand in the Mixture and Added to the Slope for Water Alone at the Same Velocity.

	3-in. Hose.	4-in. Pipe.
Water alone, C =	134	136
Velocity, 3 ft. per sec..	7.5	4.0
,, 4 ft. ,, .	5.5	3.5
,, 5 ft. ,, ,,	4.4	3.0
,, 6 ft. ,, ,,	3.7	2.8
,, 7 ft. ,, ,,	3.2	2.7
,, 8 ft. ,, ,,	2.9	
,, 9 ft. ,, ,,	2.8	
,, 10 ft. ,, ,,	2.7	
,, 11 ft. ,, ,,	2.7	

Action of Sand Ejectors. The experimental work described herein relating to sand ejectors had its beginning in connection with the design of the Water Filtration Plant at Washington, D. C., in the spring of 1904. By the authority of the officer then in charge of the Washington Aqueduct a number of tests were made under Mr. Hazen's direction to determine the power and capacity of different sizes and types of ejectors. Mr. Hazen had to experiment with, at that time, an ejector of the type used then in Philadelphia and some ejectors made from his own designs, the discharge end being patterned after the Venturi meter, and, on that account, being called a Venturi ejector.

Mr. Hazen's conception of the action of these ejectors involved from the first some more or less definite relations between pressures and velocities at the nozzle and the throat, the relative diameters of jet and throat and the quantities of material passing through the jet and throat. As a result of the first experiments mentioned in 1904, he was rewarded by finding reasonably definite relationships between these quantities, enough for him to perfect the design of the sand washing equipment at the Washington plant, which has proved itself most efficient and economical. The results of Mr. Hazen's early experiments were reviewed briefly in the paper on the filtration plant at Washington, D. C., by Messrs. Hazen and Hardy, in Vol. 57, Transactions of the American Society Civil Engineers.

As a result of these early experiments, one of his most important conclusions was the great advantage in efficiency of the

Venturi-shaped ejector over the other types of ejectors with which he experimented. The throat or discharge end of the Venturi ejector had a batter of 1 in 22. The throat of the older type of ejector used had a batter of 1 in 6. It seems that the discharge with the longer batter assisted in the recovery of part of the velocity head, or acted in some other manner to make the Venturi style much the more efficient of the two. There was not at that time, however, as much data as was needed to establish dependable laws for the action of these ejectors. It was this fact that led to further study of this problem that has been carried on since that time. During the years 1907–8 the writer carried out a large number of experiments on the action of the ejector, bringing together all the data possible upon the size of jet and throat, the pressure of water at the jet and on the discharge, the quantities of material thrown, etc. Mr. Hazen's earlier studies had made unnecessary any further comparison of the old ejectors with the sharp batter. A new type of throat had come into use at the Washington plant, however, which has been called the pipe throat. This throat was made of a piece of wrought-iron pipe, straight, cut to a length to be interchangeable with the Venturi throat. The Venturi throats wore out rapidly under the service they received, and the pipe throats made a cheap and convenient substitute therefor. The study was made, therefore, upon the two types of ejectors; first, the Venturi ejector; second, the pipe ejectors. These experiments covered the Venturi type of ejector fairly well, so that reasonably definite and certain conclusions have been drawn concerning them, and especially the advantage of this type of ejector over the old type with the sharp batter was confirmed. A large number of experiments were made with the pipe ejectors and certain conclusions concerning them were well established, but further data must be obtained before a final analysis of ejectors of this type can be made.

The analysis of the results described further on seems to indicate very much the same efficiency obtained from the Venturi ejector, and from the best designs of pipe ejectors. The results of the experiments on pipe ejectors, however, are more erratic than on the Venturi. The point upon which evidence is most needed is as to the effect of varying the length of a pipe throat of a given

diameter. In future experiments the length of the throat will be stated in terms of its diameter.

In the earlier Washington experiments it was assumed that results obtained with any given ejector carrying water alone represented what could be done with a slush of sand, weight for weight. There are so many complications and difficulties in the way of getting accurate results from ejector experiments with sand that it is much more satisfactory to study the problem with water alone if the assumption mentioned above can be shown to be a safe one. An analysis was made of a large amount of data collected during these experiments to bring out this relation which the weight of sand and water taken up bears to the weight of water alone taken up in the actual operation of the ejector. The analysis shows that, for practical purposes, it is quite safe to assume that the weight of the mixture of sand and water taken up by an ejector with perfect conditions of feed will be equal to the weight of water alone that would be taken up by the same ejector under the same conditions.

With this point demonstrated to our satisfaction, the study of the action of the ejectors proceeded with water alone. The same equipment was used for this study as was described above in the discussion of the determination of the loss of head in pipes, except that the differential mercury gage was done away with and the pressure at nozzle and throat observed by means of pressure gages. The information required from a single experiment consisted of the pressure at the nozzle, the pressure at the discharge, the quantities of water flowing to the nozzle and to the irrigator, the length of time consumed by the experiment and, of course, the exact description of the nozzle and the throat.

It was discovered early in the experiments that reliable results in the quantity of water taken up by the ejector could be obtained only with the jet continually and completely submerged. With the apparatus in shape for an experiment, therefore, the procedure was about as follows: The water was turned on at the jet until it reached the pressure desired for that particular run. The gate on the irrigator supply was then opened up wide until the jet was submerged and the water risen to a definite mark in the ejector box. It was then partially closed until the water level in the

ejector box stood just about at this mark without any but a trifling adjustment of the irrigator valve. The apparatus was then ready for the observations for a single experiment. At a definite time the two water meters were read. Readings were then taken on the two pressure gages at intervals of about fifteen seconds. At the end of a definite time the meters were read again and the experiment was ended. The valve on the nozzle supply was then adjusted to a different pressure, the valve on the irrigator supply altered to produce the same condition of equilibrium in the ejector box as before and another run was made for that pressure, and so on. The following table gives an example of the observations taken in a single run.

RUN No. A-89.

Nozzle diameter equals $\frac{5}{8}$ in.
Throat diameter equals $1\frac{1}{4}$ in. pipe throat.

Time.	Meter Readings, Jet.	Cu. Ft. Water, Irrigator.	Pressure, Lb., Jet.	Irrigator.
1.21½	252960.0	192572.5	27	6.0
			27	6.0
			28	6.0
			27	6.0
			27	6.0
			27	6.0
			27	6.0
			27	6.0
1.30	253036.5	192633.0	27	6.0
	76.5	60.5	27.1	6.0

Time elapsed	8.5 minutes.
Water passing jet	76.5 cu. ft.
Water passing throat, 76.5 plus 60.5 equals	137.0 cu. ft.
Average pressure, jet	27.1 lb. sq. in.
Average pressure, discharge	6.0 lb. sq. in.
Mean velocity in jet	70.0 ft. per sec.
Mean velocity in throat	31.5 ft. per sec.

With this data in hand the problem became one of determining the relations between pressures, quantities, jet ratios, etc., that would apply reasonably well to any case. In Mr. Hazen's earlier experiments at Washington he made a successful analysis of his

results as has already been mentioned, with his observations reduced to the following terms:

Q equals the ratio of total weight of discharge to weight of jet water.
P equals the percentage of jet pressure developed in ejector discharge.
T equals the ratio of diameter of throat to diameter of jet.
V equals ratio of throat velocity to velocity in the jet.

For the experiment given in detail above, these quantities are as follows:

Q equals 1.79
P equals .22
T equals 2.00
V equals .45

The quantities P and Q were next plotted on logarithmic paper. For each combination of jet and throat that was experimented upon a number of runs were made at different pressures on the jet, these pressures varying from the least pressure which would take up any water at all to the maximum pressure that was available. For each run a point was plotted on logarithmic paper with the quantity P as ordinate and Q as abscissa. For each set of runs upon one combination of jet and throat there were then several of these points corresponding to the different pressure conditions just mentioned. These several points were joined by lines and each broken line thus formed showed the relations between pressure and quantity for this particular ejector throughout the entire available range of pressures. When these lines had been plotted for all the different ejectors that were tried, it was found that a straight line could be drawn coinciding with the points of maximum efficiency of a great many of these curves, viz., those which represented the most efficient combinations of jet and throat. The broken lines representing the less efficient ejectors lay entirely within, but did not touch, this enveloping line. This line has been termed the curve of maximum efficiency for the ejectors. This analysis was made separately for the Venturi ejectors and for the pipe ejectors, and is shown for the former on Fig. 15. For the Venturi ejectors the equation of this curve of maximum efficiency was found to be $C=PQ^2$, and for the pipe ejectors $C=PQ^{1.7}$. For the Venturi ejector the

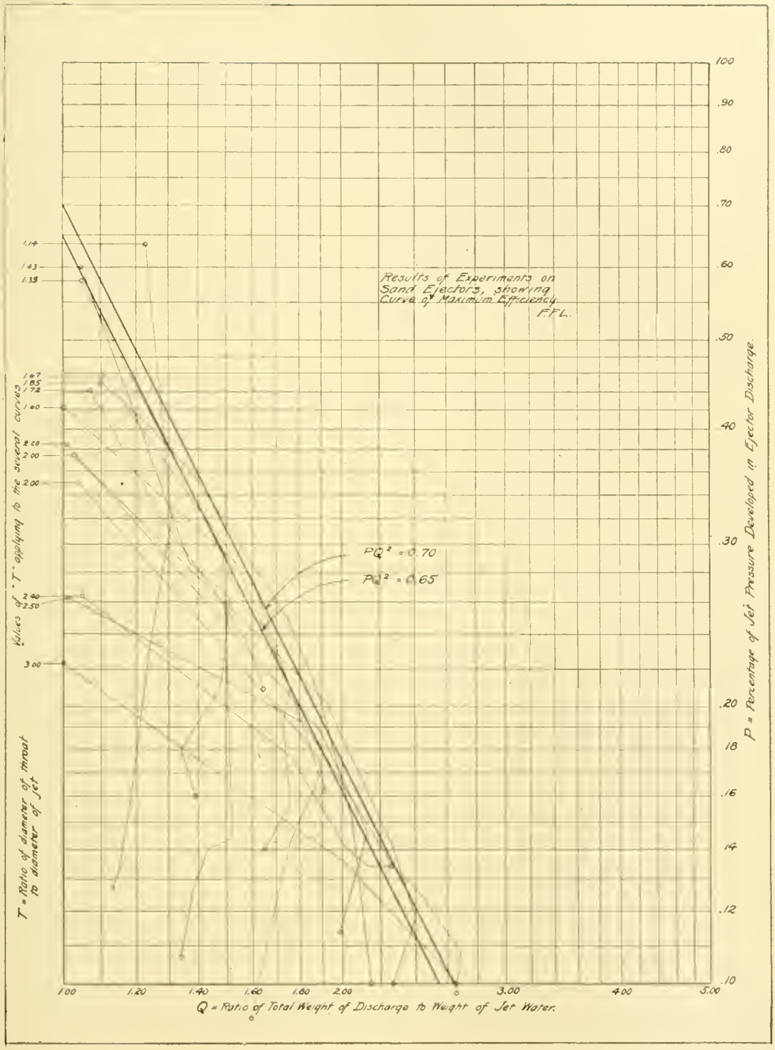


FIG. 15.

best average value of C was approximately .70, but .65 would be a more conservative figure to use for purposes of design. For the pipe ejector the best average value of C in its proper equation

was about .60, but — as in the case of the Venturi ejector — say, .55, would be a better figure to use. Within the usual range of service pressures the efficiencies indicated by these two equations differ but very little. In view of the more erratic showing of the pipe ejectors and the lack of data which will enable a more complete analysis to be made of the entire problem of pipe ejectors, the formula given above for the Venturi ejectors, viz., $C = PQ^2$, is the preferable one of the two.

Mr. Hazen, in his discussion of this paper, has brought out other relations which, together with this equation, form the fundamental equations upon which the design of sand ejectors may be based.

Messrs. Knowles and Rice. It is gratifying to the authors that their endeavors have brought to light other experiments and data upon this interesting subject, but it is to be regretted that the results of many other places where work is being done have not been chronicled, that all might have information secured under varying conditions.

Messrs. Hazen and Langley's contributions are particularly interesting and notable additions to the knowledge of the subject. The function of the irrigator, as noted by Mr. Hazen, was carefully studied in our experiments, with results as stated on page 104; where we diferentiate between the different kinds of irrigators to use with portable ejectors as compared with washers. In the latter case, only, does there seem to be an advantage with horizontal irrigator in bottom of the hopper.

Mr. Hazen's formula and accompanying tables will undoubtedly be of aid in designing works for this purpose and the handling of sand by water carriage. The authors had hoped to be able to thoroughly compare these formulæ with results of their experiments, but time has not permitted, in the desire to publish the paper, which so long has been deferred, and have the information available as soon as possible. We have thought it better to take this up at a later date.

TOPICAL DISCUSSION.

[*January 11, 1911.*]

Mr. Julius C. Gilbert.* Mr. President, I received a letter this morning relating to a small matter, but one, I think, which interests us all. It is from the superintendent of the water works of Kingston, Mass., and is as follows:

Kingston, Mass., January 9, 1911.

Superintendent Whitman Water Department,
Whitman, Mass.

Dear Sir, — Thinking you may have had a case similar to the one I am writing you about, I am seeking information on what they do in other places in cases of this kind.

Two years ago a certain party applied for town water and asked to have it metered. This I thought a fair idea, as they would use more than an ordinary family, so I had a 1½-in. connection made to the main and have been supplying them from this. It is our custom to run a service pipe of sufficient size to the curbstone line of sidewalk and to put on a curbcock, the applicant connecting on same and running his own pipe to house. In this case we put in a frost-proof meter on the town side of curbcock instead of putting it in the house cellar, as the water taken had to run in a 1½-in. galvined iron pipe 350 ft. long through a salt marsh and through a river about 25 ft. wide. Some time within the last three months this pipe burst in the marsh and of course the meter ran up enormously, registering some over two hundred and fifty dollars worth of water. What I would like to know is this: Should the user pay for this wasted water or should the water department stand for the cost of pumping it?

Yours very truly,

(Signed) Frank A. Sampson, *Superintendent.*

I suppose we have all had similar cases, and the question which this gentleman would like to have answered is what water-works officials in general do in regard to such things. I know you have all had experience of this kind, and I would like to hear from some

* Water Registrar and Treasurer, Whitman, Mass.

of you in regard to what you think would be a proper way to make a settlement.

The President. I would like to ask Mr. Gilbert if his superintendent has answered the letter, and if so, what he advised.

Mr. A. R. McCallum.* I answered Mr. Sampson's letter and told him that when we had our own pumping plant we used to bear half the loss in a case like his. When there was a large loss of water by fault of the taker, we looked up the meter reading for the previous quarter, and charged him for a like amount for the quarter the loss occurred in, plus one half the excess. As we take water now from Brockton, paying meter rates, we would have to charge what the water cost us. As the Kingston Department own their plant, I thought Mr. Sampson could make the same arrangements that we formerly did, or just charge for the cost of pumping.

Mr. Frank L. Fuller.† I think the meter not having been read once in three months emphasizes the importance of reading meters at least once a month. I think once in three months is not often enough. If the meter had been read monthly, a lot of that water would have been saved.

Mr. Gilbert. I will say, Mr. President, that it is common among the country water-works systems to read the meters only once in three months, and I presume that that is the custom in Kingston; unless it is a very large meter, where they use great quantities of water. In an ordinary case, if the pipe hadn't burst, they would probably have used not more than five to ten dollars worth of water in the three months.

I think that it makes all the difference in the world in a case like this where a pipe is located and under whose care it is. We all know that there are men, even in the state of Massachusetts, who will use water sometimes when we do not know it, if they can get at it in some way without our finding it out. I know that we have all had experiences of that kind. But in a good, honest case, as I think this to be, we have usually divided it, as our superintendent has said. I know we have had occasion to study and try to locate a leak for a month or two before we could find it, and in

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* Superintendent Water Works, Whitman, Mass.

† Civil Engineer, Boston, Mass.

cases of that kind we have always divided up upon it. The water works would lose one half and the proprietor of the house the other.

Mr. George Cassell.* I would like to state the method used in Chelsea with regard to such cases. I have no doubt it is similar to that in most other cities, in cases of the kind that the gentleman refers to, where it is a *bona fide* case of an invisible leak, and it first comes to the attention of the consumer through the meter reading. When the man reads the meter and finds that there is an abnormal consumption, and no reason can be assigned for it, we send an inspector to ferret out the cause. If in his report he demonstrates the fact that the leak was what is known as an invisible leak, and that there was no way of the consumer or the water department knowing of it except by the meter, we take the total consumption, subtract the normal consumption from that, and split the excess between the city and the consumer.

The President. I will say, Mr. Gilbert, that I believe that if we got the opinion of every one here, it would be that the answer of your superintendent was as equitable as any which could be given to the question you have asked.

Mr. Leonard Metcalf. It might in this connection be of interest to refer to the practice of the Pennsylvania Water Company, of which Mr. Hawley is the superintendent. I remember some months ago he spoke of having a good deal of trouble from cases of this kind, not so aggravated, but where the meter dials showed a considerable excess over the normal monthly consumption. Their limited earnings prevent their reading the meters monthly. They make a practice of reading the large meters monthly, but not the small meters. As I remember it, he had something over thirteen thousand or fourteen thousand meters at the time. So he established the custom of giving to the water taker the option of having the meter read monthly instead of every three months, by the payment of a nominal charge, of, as I remember it, one dollar a year, — at all events, a nominal charge to cover the bare cost of the additional work involved to the water company. If, then, the consumer does not choose to take advantage of this option and have the meter read monthly,

* Superintendent Water Works, Chelsea, Mass.

and on the three months' reading a very large excess appears, the owner is charged with substantially the whole amount. I will not say that he does not compromise the matter in some cases, because I don't know but that he does, but I know that in many cases, perhaps in most cases, he does not compromise it, the burden being assumed to be upon the water taker.

Mr. Gilbert. I want to ask the gentleman if they made the bills once a month.

Mr. Metcalf. Under the circumstances cited they did, — that is, if the water taker paid the charge covering the reading of the meter. It may be that no bill was rendered if the amount was normal, but at all events, it served to call attention forcibly to existing leakage.

Mr. Fuller. At Wellesley, a year or two ago, we sent out a card showing a meter and the way in which it is read, explaining the reading of the meter, and asked the consumers to occasionally at least read their meters and see how the consumption was going on. I think that has done some good, and it has to a certain extent relieved the water board of some responsibility. However, we have just adopted a method whereby we have a card which is placed near the meter, and the reading for each month is recorded on that card, and we call the attention of the consumer to this. It seems to us that if in case of a leak we can show the consumer that he has a record every month of how much water he was using, it places still greater responsibility upon him.

REPORT OF THE COMMITTEE TO LOOK AFTER AND KEEP TRACK OF LEGISLATION AND OTHER MATTERS PERTAINING TO THE CONSERVATION, DEVELOPMENT, AND UTILIZATION OF THE NATURAL RESOURCES OF THE COUNTRY.

[*Presented January 11, 1911.*]

A detailed report from this committee seems uncalled for in view of the fact that probably most of the members of the Association are as well posted as the members of the committee on the chief happenings in the conservation field during the past year.

The most notable conservation event of 1910 was the Conservation Congress held at St. Paul in September. That little of technical interest occurred at this conference was the opinion of a committee of the Engineers' Society of Western Pennsylvania, which has recently submitted a report to the society named urging that that society lead in the movement to establish an Engineering Section at future conferences. If this suggestion bears fruit, it may be desirable for the committee of this Association to coöperate.

Large withdrawals of public lands containing mineral resources were made about the middle of the year by President Taft under specific congressional authority. Considerable portions of the land covered by these withdrawals had previously been withheld from settlement, but President Taft and his supporters believed that specific authorization was necessary, and such authorization was granted by Congress.

At the St. Paul Conservation Congress, already mentioned, an address was delivered by President Taft, in which he outlined his own policies regarding many important phases of conservation. On the question of water power, which perhaps more directly concerns the members of this Association than the other topics, the President presented a somewhat closely balanced judicial review of many of the points at issue. The whole address is well

worthy of careful reading and consideration, if for no other reason than because it gives an up-to-date inventory of the natural resources still owned by the United States.

A number of states have conservation commissions at work, but for the most part these commissions have done nothing as yet save to review the resources of the states which they represent and to suggest lines for future action.

As a whole, it cannot be said that the conservation movement has as yet resulted in very much definite constructive work, but it has served to call emphatic attention to the need of statesmanlike consideration of and action upon the whole subject. This has been eminently useful, since a vast amount of educational work in arousing interest and enthusiasm was necessary in order to pave the way for needed reforms.

An announcement has just been made of a new illustrated magazine to be called *American Conservation*. This publication will, apparently, be the organ of the National Conservation Association, which has its headquarters in the Colorado Building, Washington, D. C., and has as its president, Mr. Gifford Pinchot, recently Chief Forester of the United States. It is expected that the magazine will present its readers with full information regarding the progress of the conservation movement — national, state, municipal, and private.

For the committee,

M. N. BAKER,
Chairman.

REPORT OF COMMITTEE ON HYDRANT SPECIFICATIONS.

[*Presented January 11, 1911.*]

Mr. President and Gentlemen of the New England Water Works Association, — On behalf of the Committee on Hydrant Specifications I wish to present the following report.

In line with the discussion of the hydrant specifications at the annual meeting of the Association on January 12, 1910, the committee arranged for a joint conference with the hydrant manufacturers. This meeting took place on February 24, nine manufacturers being represented.

Practically all of the important items in the specifications as proposed at the last annual meeting of the Association were discussed at length, and the manufacturers were requested to submit to the committee in writing such amendments and additions as they thought should be made to the specifications. This they agreed to do.

Some time later the manufacturers held one or more meetings among themselves and prepared a complete set of specifications, following the general arrangement previously proposed by the committee, but differing from those specifications in several important features. The manufacturers sent the committee a copy of their specifications in printed form, with letter dated July 21. These specifications were submitted after having been fully considered by fourteen of the hydrant manufacturers.

It was at once seen that some of the items were open to serious question, and at least one of them was manifestly absurd, namely, a specification to permit a friction loss of twenty pounds in a two-way hydrant with two streams flowing (five hundred gallons per minute), whereas the present commercial hydrants give probably much less than five pounds under the same conditions. However, the consideration of these specifications was held for the moment, pending the results of tests of hydrants, arrangements

for which were then already being made, as mentioned later in this report.

The item which perhaps received the most attention at the February conference was the one relating to the diameter of the valve opening, and it was proposed by some if not all of the manufacturers present that, as regards friction loss and discharge capacity, a 5-in. opening was unnecessarily large for a two-way hydrant, and that a 4-in. opening was probably sufficient. This at once raised the question as to the friction loss and discharge capacity of the present hydrants having 4-in. openings, but all of the manufacturers agreed that they had made no tests and were unable to give this information.

It was promptly suggested, therefore, that sample hydrants be tested, as the next step in the work of the committee, and the committee agreed to arrange if possible for the facilities for such tests. The manufacturers on their part agreed to furnish whatever hydrants might be desired by the committee for this purpose.

It was thought that later a second series of tests might be made on hydrants with 5-in. valve openings, for comparison with the results obtained in these first series of tests of hydrants with 4-in. valve openings.

During the summer arrangements for the testing facilities were completed, thanks to Mr. F. A. McInnes, a member of your committee and also at that time acting city engineer of the city of Boston.

On August 27, a circular letter was sent to the several hydrant manufacturers, stating that the committee was ready to begin the work of testing, and asking that sample 2-way hydrants having 4-in. valve openings be sent for the proposed tests.

Several of the manufacturers at once replied stating that the hydrants would be sent promptly. One manufacturer, however, who was also represented on the special committee appointed by the manufacturers to take up this matter of hydrant specifications in conjunction with your committee, objected to sending the hydrants until certain details regarding the conduct of the tests were definitely agreed upon by the committee.

It was considered that some of these points were entirely unimportant, that others were matters which could not very easily

be determined by the committee until the hydrants were in hand, and there were still other questions asked which it was believed could best be answered only after the tests were completed. I therefore wrote this manufacturer along this line, but evidently was unable to satisfy him, and later, when the whole matter came before a meeting of the manufacturers held September 20, they refused to send the hydrants, among the manufacturers definitely taking this action being those who had previously expressed their willingness to send the desired samples.

At the same time the manufacturers requested that the committee advise them regarding the specifications which they had submitted to the committee in July.

The only courses then open to the committee for obtaining hydrants for the tests appeared to be to either buy, borrow, or steal. The Association had made no appropriation for such an unusual expenditure, the chairman of the committee did not know where to go to borrow, and we were all too law-abiding to steal. We have, therefore, had no hydrants to test and the tests have not been made.

During the past two or three months work incident to the closing of the year has prevented me from giving the matter further consideration, and I anticipate that the other members of the committee have been in much the same situation.

However, in order to advance the work of the joint consideration of these specifications by the committees of the National Fire Protection Association and the American Water Works Association, copies of the specifications as proposed at the last annual meeting of the New England Water Works Association and of the specifications prepared by the hydrant manufacturers have recently been sent to the members of those committees, and in due time it is expected that a joint conference will be held to further consider the whole matter.

While the committee were familiar with the hydrant tests made by Charles L. Newcomb at Holyoke in 1897 and 1898, on a number of the hydrants then in common use, it was believed that tests on the present makes of hydrants were desirable as showing strictly up-to-date conditions. The information which such tests would provide would be of much value to the committee in connection

with the work in hand, and we certainly expected that these tests would be made during the past year, so that we could present to the Association to-day a final report. We, however, regret that we are unable to do this, and instead can only report that considerable effort has been made to this end but without practical result.

We are particularly disappointed that the manufacturers have so signally failed to coöperate with the committee, refusing the assistance which they easily could have rendered in obtaining information which at the February conference it was considered would be of value to the committee in connection with the work in hand.

Just what help the committee may expect from the manufacturers in future, time only can tell; we do not know. Neither do we understand the present attitude of the manufacturers in this matter of hydrant specifications.

Under the conditions we are obliged to recommend that the specifications as printed in the Proceedings of the annual meeting of 1910 be still considered as the tentative specifications of the Association; and we would repeat the request of a year ago that the committee be favored with the suggestions which any member of the Association may have regarding this subject.

Respectfully submitted,

H. O. LACOUNT,
Chairman.

REPORT OF COMMITTEE ON UNIFORMITY OF HOSE AND GATE NUTS AND DIRECTION OF OPENING.

BY FRANK L. FULLER.

[*Read January 11, 1911.*]

Your committee owes an apology to the Association for not having done anything since 1906. At that time a report was made * and the committee continued. But the fact dropped out of our minds, or it did out of mine, and it was only on receiving a communication from the Secretary in regard to it that it was brought to our attention again.

That report, as you remember, was in regard to the manner in which gates and hydrants should open, and the size of gate nuts, and your committee recommended that gates and hydrants should open to the left, as that seemed to be the best way to secure uniformity, all steam valves opening in that direction, and, of course, a certain proportion of water-works valves and hydrants.

At the time of that report the question was brought up and was discussed as to independent valves which are often placed in three-way and four-way hydrants. The question was raised as to the size of the spindle and of the nut operating the $2\frac{1}{2}$-in. valve, and the committee was asked to report on the matter. Your committee now presents that report.

The Committee on Proposed Specifications for Post Hydrants a year ago † went into the matter particularly, and recommended that the stems be $\frac{3}{4}$ in. in diameter, with a stem nut $\frac{3}{4}$ in. square. This committee agrees with these suggestions.

In regard to the direction of opening, this committee is of the same opinion as expressed in our previous report, namely, that unless there are reasons as therein expressed, they should open to the left.

While the committee realizes that there are many hydrants in use with these independent hose-gate valves, they feel that, except

* JOURNAL N. E. W. W. A., Vol. XX, p. 348.
† JOURNAL N. E. W. W. A., Vol. XXIV, p. 205.

perhaps in mill yards where they are used by men who are entirely familiar with the direction of opening and the amount of leverage which should be used in opening them, and the number of turns required, for the use of the average fireman it is better to use a valve with a proper sized handwheel, screwed directly to the hose nozzle, and the hose connected with this $2\frac{1}{2}$-in. gate valve.

Hydrants are made with a valve permanently connected to the hose opening, but the projection of this valve is objectionable in street hydrants, and they would be liable to injury, as pointed out by Mr. Stacy, by the small boy or the maliciously inclined.

There are no doubt points, especially in mill yards, where a three- or a four-way hydrant will do excellent service, but as a four-way hydrant with independent hose gate valves costs about double an ordinary two-way hydrant, the question may be raised whether the two two-way hydrants are not more desirable. They are simpler, and simplicity is always desirable.

This committee recommends that the fire department hose wagons carry a sufficient number of gate valves which can be screwed to the hydrants and the hose attached to these valves, the valves to be operated by a hand wheel.

A letter dated December 5, 1906, from Mr. A. W. F. Brown, water registrar, Fitchburg, treats of this subject from a practical standpoint, and the committee, therefore, adds it to their report.

Respectfully submitted,

F. L. FULLER.
FRANK C. KIMBALL.

FITCHBURG, MASS., December 5, 1906.

MR. FRANK L. FULLER,
12 PEARL STREET, BOSTON, MASS.

Dear Sir, — In reply to yours about hydrants with independent valves, would say that we have about 128 four-way hydrants in use on pressures from 72 to 180 pounds to the square inch, and they are all right if handled properly. They are of the Chapman make and are a fine working hydrant. The independent valves are as strong as the room in the top of the hydrant will allow of making them, and will stand all the strain necessary to work the valves,

but they will not stand a man pulling on them with the leverage that the hydrant wrench will give.

The firemen sometimes leave the main valve open, having shut off the streams with the small valves, and forgetting to close the main one, and the highway department do the same. In cold weather this means a frozen hydrant soon after. The men also get excited sometimes and try to turn them the wrong way, and in that condition something has to come, and the valve is usually broken. The main valve will stand all their pulling without harm, and the small ones would if they had only the leverage that there is to a wheel valve.

The highway department sometimes leaves the small valves open and the firemen start to use it, and after attaching one line of hose and getting water, take off another cap for the second line, receiving the full $2\frac{1}{2}$-in. stream, and, flying over to the other side of the road, wonder what hit them. We have never had a man hurt from being hit this way, but have had them wet several times, with narrow escapes from serious accidents. Of course they make remarks about the water department, and their lack of attention to the hydrants, but as we have not full control over their use, we cannot always know when they are used and so look them over to see their condition. We intend to look them over after being used at a fire as soon as the firemen are through.

We do not have a great amount of trouble from them, but just enough to convince me that I would rather have the hydrants without them, even if we gave the fire department a new set of valves every year or two to use on the nozzles. They carry a valve on the line of hose on each wagon to use on the two-way hydrants, and they could just as well use the others the same way.

Yours very truly,

(Signed) A. W. F. Brown,

Registrar.

Mr. George A. Stacy.* Mr. Brown's letter simply emphasizes the necessity of the water department controlling the hydrants, and also emphasizes the fact that hydrants are made for fire service and not for flushing streets, or to be monkeyed with by

* Superintendent Water Works, Marlboro, Mass.

people who don't know anything about them and who want to use them for all other purposes.

Mr. Martin.* I think all of us who have anything to do with hydrants will echo Mr. Stacy's remarks. I move that this report be accepted as a report of progress.

Mr. Fuller. I think this committee has been in existence about long enough and I hope the report will be accepted and the committee discharged, because this matter would very naturally come before the Committee to Prepare a Standard Specification for Fire Hydrants, and it seems to me unnecessary to have two committees so nearly alike.

Mr. Julius C. Gilbert.† I think this committee is doing well so far. I notice particularly that they recommend that the valve gates open to the left, and after my experience I should say that was right. It seems to me that we are going to have pretty hard work to get specifications for hydrants which will please every one. I can hardly wonder myself that the manufacturers of hydrants do not take to this so kindly as some of the water-works people, for the reason that, as you know, it is pretty hard work to bring all our water-works people to the same mind in regard to a hydrant. I think that as long as hydrants are made there will be different kinds or different makes of hydrants which will differ in some respects. This committee may get up a pattern of a hydrant which we might feel perfectly satisfied with, and in three months from now some one will get up a hydrant that is still better. So it looks to me as though it would be a pretty difficult matter to get a hydrant that will suit everybody.

Mr. J. C. Hammond, Jr.‡ When we built our water works the question of right or left for gates and hydrants came up, and we settled it on the principle that the normal condition of a hydrant is closed, and, therefore, the nut is turned to the left, while the normal condition of a gate on the main line is open, and, therefore, we turn to the right, and there is no confusion.

The motion to accept the report as a report of progress was adopted.

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* Superintendent Water Works, Springfield, Mass.
† Water Registrar and Treasurer, Water Works, Whitman, Mass.
‡ Secretary and Treasurer, Rockville Water Company, Rockville, Conn.

PROCEEDINGS.

Annual Meeting.

Hotel Brunswick,
Boston, January 11, 1911.

President King in the chair.

The following members and guests were present:

Honorary Member.

F. P. Stearns.

Members.

S. A. Agnew, A. F. Ballou, L. M. Bancroft, G. W. Batchelder, W. L. Beals, F. D. Berry, J. W. Blackmer, C. A. Bogardus, George Bowers, Dexter Brackett, E. C. Brooks, G. A. P. Bucknam, G. A. Carpenter, George Cassell, J. C. Chase, M. F. Collins, E. R. Dyer, E. D. Eldridge, G. H. Finneran, F. F. Forbes, F. J. Gifford, J. C. Gilbert, Albert S. Glover, J. A. Gould, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, J. C. Hammond, Jr., Allen Hazen, H. G. Holden, W. S. Johnson, E. W. Kent, Willard Kent, F. C. Kimball, G. A. Kimball, G. A. King, A. R. McCallum, N. A. McMillen, D. E. Makepeace, A. E. Martin, W. E. Maybury, John Mayo, F. E. Merrill, G. F. Merrill, Leonard Metcalf, William Naylor, A. S. Negus, F. L. Northrop, E. M. Peck, T. A. Peirce, W. H. Richards, Henry Roberts, C. W. Sherman, J. Waldo Smith, G. H. Snell, G. A. Stacy, W. F. Sullivan, L. A. Taylor, H. L. Thomas, R. J. Thomas, W. H. Thomas, L. D. Thorpe, J. L. Tighe, J. A. Tilden, D. N. Tower, C. H. Tuttle, W. H. Vaughn, C. K. Walker, J. H. Walsh, R. S. Weston, H. L. Whitney, F. B. Wilkins, G. E. Winslow. — 74.

Associates.

Anderson Coupling Company, by C. E. Pratt and C. E. Childs; Ashton Valve Company, by C. W. Houghton and Columbus Dill; Harold L. Bond Company, by F. M. Bates; Builders Iron Foundry, by G. H. Lewis and A. B. Coulters; Chapman Valve Manufacturing Company, by A. W. Hobbs; Darling Pump and Manufacturing Company, Ltd., by H. H. Davis and J. L. Hough; The Fairbanks Company, by W. D. Cashin; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, and W. A. Hersey; International Steam Pump Company, by E. F. Nye; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould and A. R. Taylor; Chas. Millar & Son Company, by C. F. Glavin;

H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by H. L. Weston and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall and Edw. P. King; United States Cast Iron Pipe and Foundry Co., by D. B. Stokes; Waldo Bros., by H. E. Browne; Water Works Equipment Company, by H. M. Heim; R. D. Wood & Co., by C. R. Wood and Wm. Woodburn. — 35.

Guests.

F. L. Weaver, G. W. Bowers, and E. H. Foye, Lowell, Mass.; William Harvey, superintendent water works, and Joseph Woods, water commissioner, Pawtucket, R. I.; Alvin C. Howes, Middleboro, Mass.; J. Kelley, Braintree, Mass.; F. Woodbury, 2d, water commissioner, Beverly, Mass., and Raymond C. Allen, Manchester, Mass.; H. P. Plimpton, water commissioner, Walpole, Mass. — 10.

The Secretary read applications for membership from Henry E. Warren, Ashland, Mass., chairman of the water commissioners, Ashland, Mass.; and A. Lincoln Fellows, Denver, Colo., engaged in irrigation and water supply work, and a member of the Utilities Commission, Denver.

On motion of Mr. Fuller, the Secretary was instructed to cast the ballot of the Association in favor of the applicants, and he having done so, they were declared elected to membership.

Raymond C. Allen, C.E., Manchester, Mass., presented a paper on "The Gas Producer Pumping Plants at Manchester, Massachusetts." The paper was discussed by Mr. Harry L. Thomas, Mr. Frank L. Fuller, and Mr. John C. Chase.

Mr. Allen Hazen read the report of Mr. M. N. Baker, chairman of the committee to "look after and keep track of legislation and other matters pertaining to the conservation and development and utilization of the natural resources of the country."

On motion of Mr. Pierce, the report was accepted and ordered placed on file, and the committee continued.

Mr. H. O. Lacount, chairman, read the report of the committee "to prepare a standard specification for fire hydrants."

On motion of Mr. Fuller, the report was received as a report of progress, and the committee continued.

Mr. Frank L. Fuller, chairman, presented the report of the committee "on uniformity of hose and gate nuts, and direction of opening."

The report was discussed by Mr. George A. Stacy, Mr. Julius C. Gilbert, and Mr. J. C. Hammond, Jr., and was accepted as a report of progress.

The report of the committee "to compile information relating to awards that have been made in water-works valuation cases," H. W. Dean, chairman, was called for. Secretary Kent, in the absence of Mr. Dean, reported that Mr. Dean has endeavored faithfully to gather material for the report, but has not been successful. He has sent out two different circulars, without being able to secure sufficient information in response to warrant making a report, as people who had the information did not like to part with it.

The following reports of officers of the Association were received.

REPORT OF TREASURER.

LEWIS M. BANCROFT, TREASURER,
In account with the New England Water Works Association.

RECEIPTS.

1910.				
Jan.	1	Balance on hand		$3 449.57
Aug.	1	Dividend People's Saving Bank, Worcester		69.94
Nov.	1	Coupons, L. S. & Mich. So. R. R. bonds,		80.00
Dec.	1	Dividend, Mechanics Savings Bank, Reading		36.54
		Interest on deposits		1.14
		Rec'd of Willard Kent, Sec'y,	$5 369.46	
		Rec'd of Willard Kent, Sec'y, lunches	750.00	
		Rec'd of Willard Kent, Sec'y, June excursion	200.00	6 319.46
				$9 956.65

EXPENDITURES.

Paid bills, as per itemized statement		$7 237.60
BALANCE ON HAND.		
Deposit	People's Savings Bank, Worcester	1 801.80
,,	Mechanics Savings Bank, Reading	900.00
,,	Liberty Trust Co., Boston	16.39
,,	First National Bank, Reading	.86
		$9 956.65

ASSETS AND LIABILITIES.

ASSETS.

Cash in banks	$2 719.05
Bonds Nos. 2642 and 2644, Lake Shore & Mich. So. R. R. 4%, due May 1, 1931. Book value, $1 815.00. Market value	1 870.00
	$4 589.05

LIABILITIES.

Accounts payable:	
Assistant Secretary, expense	$14.94
Editor's salary	75.00
Expense	12.55
Printing December JOURNAL	748.95
Samuel Usher	83.25
Net assets in hands of Treasurer	3 654.36
	$4 589.05

LEWIS M. BANCROFT, *Treasurer.*

Examined and found correct,
JOHN C. CHASE,
GEORGE H. FINNERAN, } *Auditing Committee.*

JANUARY 11, 1911.

DETAILED STATEMENT OF BILLS PAID.

1910.			
January	17	W. N. Hughes, dues book and cards	$10.00
		Samuel Usher, advance copies Hydrant Specifications	3.50
		Bacon & Burpee, reporting November and December meetings	52.50
		D. Gillies' Sons, printing ballots and envelopes .	18.50
		The Brunswick, music at January meeting . . .	15.00
	24	Miss J. M. Ham, salary for January	50.00
		Chas. W. Sherman, salary as advertising agent to January 1	56.00
February	4	Richard K. Hale, salary as editor to December 31, 1909	75.00
		Richard K. Hale, expenses	7.00
		Samuel Usher, December, 1909, JOURNAL and reprints	886.97
		Boston Society of Civil Engineers, rent to December 1, 1909	100.00
		L. M. Bancroft & Son, treasurer's bond	17.50
		W. N. Hughes, stamped envelopes and printing .	65.00
	12	W. N. Hughes, printing	33.00
	18	The Brunswick, lunch, cigars, and music, February 4	164.50
		W. N. Hughes, binding and blocking	3.55
March	5	Suffolk Engraving and Electrotyping Company, plates	2.80
		Miss J. M. Ham, salary for February	50.00
		Boston Society of Civil Engineers, rent to February 28	100.00
		Leonard Metcalf, library research, 1909	21.65
	15	D. Gillies' Sons, envelopes and printing	86.72
		W. N. Hughes, printing	46.50
		The Brunswick, lunches, music, and cigars, March 9, 1910	171.50
		Thomas P. Taylor, stereopticon	10.00
	19	Suffolk Engraving and Electrotyping Company, plates	7.05
	22	J. C. Halden, drawing	2.50
	23	Richard K. Hale, salary as editor to March 31 .	75.00
		Richard K. Hale, postage and expenses	8.45
		R. J. Thomas, salary as advertising agent to April 1	55.50
		Miss J. M. Ham, salary for March	50.00
		Amount carried forward	$2 245 69

	Amount brought forward	$2 245.69
March 23	Samuel Usher, printing cards and circulars	7.25
April 4	Samuel Usher, printing March JOURNAL and reprints	1 006.85
	Suffolk Engraving and Electrotyping Company, plates	2.68
13	Allyn House, Hartford, dinners, cigars, and music	193.58
16	W. N. Hughes, printing	62.00
	Willard Kent, salary to March 31	50.00
	Willard Kent, expenses	39.98
22	L. S. Cowles, expense committee on engineering building	15.00
	Bacon & Burpee, reporting January, February, March, and April meetings	131.30
30	Miss J. M. Ham, salary for April	50.00
May 12	W. N. Hughes, printing	18.50
	D. Gillies' Sons, printing	35.25
14	Chas. Dunkelberger, printing	4.00
	Wm. F. Woodburn, stationery	5.60
28	Suffolk Engraving and Electrotyping Company, plates	1.28
28	Boston Society of Civil Engineers, rent to May 31,	100.00
	Miss J. M. Ham, salary for May	50.00
	Miss J. M. Ham, expenses	69.90
June 13	Richard K. Hale, salary to June 30	75.00
	Richard K. Hale, express and postage	8.70
16	D. Gillies' Sons, printing	6.00
	Samuel Usher, printing list of members and constitution	175.50
22	R. J. Thomas, salary to June 30	63.00
	Providence, Fall River and Newport Steamboat Company	75.00
	S. S. Atwell Co., dinners	74.25
	Geo. A. King, expense conference on Uniform Accounting	39.40
	Irving S. Wood, expenses for June outing	40.65
July 5	D. Gillies' Sons, printing	26.75
7	Suffolk Engraving and Electrotyping Company, plates	9.41
	Samuel Usher, June JOURNAL and reprints	309.20
12	Miss J. M. Ham, salary for June	50.00
18	Pulsifer Paper Company, printing	3.50
	Willard Kent, salary to July 1	50.00
	Amount carried forward	$5 095.22

		Amount brought forward	$5 095.22
July	18	Willard Kent, expenses	5.00
	30	Suffolk Engraving and Electrotyping Company, plates	11.55
August	5	Miss J. M. Ham, salary for July	50.00
	18	Suffolk Engraving and Electrotyping Company, plates	6.72
	31	D. Gillies' Sons, printing circulars	10.25
		W. N. Hughes, envelopes	3.75
		Miss J. M. Ham, salary for August	50.00
September	28	Richard K. Hale, salary to September 30	75.00
		Richard K. Hale, copyright September JOURNAL,	1.00
October	5	R. J. Thomas, salary advertising agent to September 30	63:00
		W. N. Hughes, envelopes and printing	49.50
		Miss J. M. Ham, salary for September	50.00
		W. F. Woodburn, fittings for exhibit	34.41
		Willard Kent, salary to October 1	50.00
		Willard Kent, expense	31.80
		Samuel Usher, reprints	32.74
		Bacon & Mudge, report of annual convention,	110.00
	26	American Society of Civil Engineers, binding,	4.00
		Boston Badge Company, badges	51.80
		W. N. Hughes, envelopes	45.00
		Wm. E. Whittaker, tracing and lettering	2.50
November	2	The Evening Post Job Printing Office, electroplate	1.80
		Suffolk Engraving and Electrotyping Company, plates	7.40
		Samuel Usher, September JOURNAL	277.65
	10	Miss J. M. Ham, salary for October	50.00
		Miss J. M. Ham, expenses	85.01
		W. N. Hughes, printing circulars	5.00
		Suffolk Engraving and Electrotyping Company, plates	14.85
	23	D. Gillies' Sons, printing	29.50
		The Brunswick, lunches, November 9	184.50
December	9	Miss J. M. Ham, salary for November	50.00
		Suffolk Engraving and Electrotyping Company, plates	8.82
	19	Lewis M. Bancroft, salary as treasurer	50.00
		Boston Society of Civil Engineers, rent to December 31	233.33
		Amount carried forward	$6 831.10

	Amount brought forward	$6 831.10
December 31	Bacon & Mudge, reporting November and December meetings	49.50
	Miss J. M. Ham, salary for December	50.00
	The Brunswick, lunch, music, and cigars, December meeting	195.00
	H. K. Higgins, stereopticon	12.00
	W. N. Hughes, printing circulars	1.50
	Willard Kent, salary to December 31	50.00
	Willard Kent, expenses	10.00
	D. Gillies' Sons, circulars and ballots	38.50
		$7 237.60

SUMMARY OF BILLS PAID.

1909 Bills Paid.

Office:			
Rent	$133.33		
Printing	28.50		
		$161.83	
JOURNAL:			
Reporting	$52.50		
Printing	886.97		
Editor's salary and expenses	82.00		
Advertising agent	56.00		
		1 077.47	
Committees:			
Printing	$3.50		
Library search	21.65		
		25.15	
			$1 264.45

1910 Bills Paid.

JOURNAL:		
Advertising agent	$181.50	
Plates	74.36	
Printing	1 626.44	
Reporting	290.80	
Editor's salary	225.00	
Editor's expenses	23.15	
Envelopes and circulars	52.25	
		$2 473.50

Office:			
Secretary, salary	$200.00		
Secretary, expense	86.78		
Assistant Secretary, salary	600.00		
Assistant Secretary, expense	154.91		
Rent	400.00		
List of members	175.50		
Library	7.55		
Printing, stationery, postage	200.25		
		$1 824.99	
Meetings and Committees:			
Stereopticon	$22.00		
Lunches, cigars, and music	924.08		
Badges	51.80		
June excursion	216.65		
Committee on Engineering Building	15.00		
Committee on Uniform Accounts	39.40		
Committee on Exhibit	34.41		
Envelopes and postage	118.25		
Printing	98.85		
		1 520.44	
Treasurer's salary and bond		67.50	
Stationery		86.72	
			$5 973.15
			$7 237.60

NEW ENGLAND WATER WORKS ASSOCIATION.

Year.	President.	Membership at End of Year. Members.	Associate.	Honorary.	Total.	Annual Convention. Place.	Date.	Receipts.	Expenditures.	Cash Balance.
1882	(Organized)	27	—	—	27	Boston, Mass.	June 21, '82			
1882–3	*James W. Lyon	37	6	—	43	Worcester, Mass.	June 21, '83	$245.00	$87.86	$157.14
1883–4	Frank E. Hall	48	9	—	57	Lowell, Mass.	June 19–20, '84	156.14	171.90	141.38
1884–5	*George A. Ellis	83	44	—	127	Springfield, Mass.	June 18–19, '85	651.84	511.44	281.78
1885–6	R. C. P. Coggeshall	106	47	—	153	New Bedford, Mass.	June 16–18, '86	1 658.50	1 643.42	296 86
1886–7	*Henry W. Rogers	137	52	2	191	Manchester, N. H.	June 15–17, '87	1 342.28	1 066.98	572.16
1887–8	*Edwin Darling	181	54	3	238	Providence, R. I.	June 13–15, '88	2 013.30	1 697.15	888.31
1888–9	*Hiram Nevons	209	64	4	277	Fall River, Mass.	June 12–14, '89	2 204.07	2 127.70	964.68
1889–90	Dexter Brackett	257	73	5	335	Portland, Me.	June 11–13, '90	2 511.27	2 346.65	1 129.30
1890–1	*Albert F. Noyes	281	74	5	360	Hartford, Conn.	June 10–12, '91	3 055.13	1 884.78	2 299.65
1891–2	Horace G. Holden	290	70	5	365	Holyoke, Mass.	June 8–10, '92	2 887.17	3 278.54	1 908.28
1892–3	*George F. Chace	338	69	5	412	Worcester, Mass.	June 14–16, '93	3 422.61	3 317.22	2 013.67
1893–4	*Geo. E. Batchelder	365	73	5	443	Boston, Mass.	June 14–16, '94	3 208.85	3 259.07	1 963.45
1894–5	George A. Stacy	401	81	5	487	Burlington, Vt.	Sept. 11–13, '95	3 147.41	3 115.99	2 673.03
1895–6	Desmond FitzGerald	442	82	5	529	Lynn, Mass.	June 10–12, '96	3 179.91	3 148.49	2 704.45
1896–7	*John C. Haskell	464	80	5	549	Newport, R. I.	Sept. 8–10, '97	3 340.23	3 322.94	2 721.74
1897–8	Willard Kent	488	77	5	570	Portsmouth, N. H.	Sept. 14–16, '98	3 002.13	2 786.95	2 936.92
1898–9	Fayette F. Forbes	494	73	5	572	Syracuse, N. Y.	Sept. 13–15, '99	2 825.71	3 050.23	2 712.40
1899–1900	Byron I. Cook	519	70	5	594	Rutland, Vt.	Sept. 19–20, '00	4 920.49	5 524.65	2 108.24
1901	Frank H. Crandall	493	58	4	555	Portland, Me.	Sept. 18–20, '01	4 238.55	4 283.22	2 063.57
1902	Frank E. Merrill	522	60	5	587	Boston, Mass.	Sept. 10–12, '02	5 158.48	4 680.32	2 541.73
1903	Charles K. Walker	520	55	3	586	Montreal, Canada	Sept. 9–11, '03	5 032.40	4 505.08	3 069.05
1904	Edwin C. Brooks	538	58	8	604	Holyoke, Mass.	Sept. 14–16, '04	5 328.31	5 528.21	2 869.15
1905	George Bowers	584	53	8	645	New York, N. Y.	Sept. 13–16, '05	5 431.16	5 411.58	2 888.73
1906	Wm. T. Sedgwick	618	51	15	684	White Mts., N. H.	Sept. 12–14, '06	5 366.94	4 845.14	3 410.53
1907	John C. Whitney	636	51	15	792	Springfield, Mass.	Sept. 11–13, '07	5 291.83	†4 222.06	4 480.30
1908	Alfred E. Martin	633	49	14	696	Atlantic City, N. J.	Sept. 23–25, '08	5 706.36	7 475.56	‡2 711.10
1909	Robert J. Thomas	647	55	13	715	New York, N. Y.	Sept. 8–10, '09	5 305.31	†4 566.84	‡3 449.57
1910	George A. King	678	56	13	747	Rochester, N. Y.	Sept. 21–23, '10	6 507.08	†7 237.60	‡2 719.05

* Deceased. † Not including December Journal and reprints. ‡ Does not include $1 815 invested in bonds.

The Secretary, Mr. Willard Kent, submitted the following report:

Report of the Secretary.

Mr. President and Members of the New England Water Works Association, — Your Secretary submits the following report of the general condition of the Association and of changes in the membership for the year ending December 31, 1910.

MEMBERSHIP.

The present membership of the Association is 747; that of one year ago was 715, a gain of 32 during the year.

The detailed statement of the changes in membership during the past year in the several grades is as follows:

MEMBERS.

January 1, 1910.	Total members		647		
	Withdrawals:				
	Resigned	10			
	Died	6			
	Dropped	24	40		
		—	—	607	
	Initiations:				
	January	3			
	February	8			
	March	1			
	April	12			
	June	13			
	September	9			
	November	3			
	December	2	51		
		—			
	Two members elected in 1909, but qualified in 1910		2		
			—	53	
	Reinstated:				
	Member dropped in 1907	1			
	Members dropped in 1909	2			
	Member resigned in 1909	1			
	Members dropped in 1910	14		18	
		—		—	678

HONORARY MEMBERS.

January 1, 1910.	Honorary members				13

ASSOCIATES.

January 1, 1910.	Total associates		55		
	Withdrawals:				
	Resigned	4			
	Dropped	5	9		
		—	—	46	
	Initiations:				
	January	1			
	April	2			
	September	4			
		—		7	
	Reinstated:				
	Associate resigned in 1905		1		
	Associates dropped in 1910		2	3	56
January 2, 1911.	Total membership				747

DIED.

D. H. Gilderson, superintendent water works, Haverhill, March 14, 1910.
W. J. Goldthwait, Marblehead, Mass., December 7, 1909.
J. W. Goodell, water commissioner, Burlington, Vt., October 9, 1909.
William Jackson, city engineer, Boston, Mass., June 30, 1910.
C. H. Rollins, water commissioner, Watertown, Mass., July 20, 1910.
N. P. Simin, civil engineer, Moscow, Russia, July 17, 1909.

SUMMARY OF RECEIPTS OF THE NEW ENGLAND WATER WORKS ASSOCIATION FOR THE YEAR 1910.

Receipts.

Initiation	$275.00
Dues	2 870.00
Advertising	1 736.25
Subscriptions	168.00
JOURNAL	196.50
Lunches	950.00
Reprints	60.42
Specifications	43.55
Sundries	19.74
	$6 319.46

SUMMARY OF DISBURSEMENTS CERTIFIED BY SECRETARY FOR THE YEAR 1910.

On account of Journal	$1 044.02
Stationery and printing	667.55
Assistant Secretary	600.00
Incidental expenses	298.46
Rent	533.33
On account of Editor	150.00
Secretary	200.00
Advertising agent	237.50
June excursion	189.90
On account of stenographer	52.50
Reprints	32.00
Hotel lunches	924.08
Stereopticon	22.00
Badges	51.80
Library	6.75
Insurance	17.50
Total of bills certified by Secretary	$5 027.39
Additional bills paid per Treasurer's report	2 210.21
	$7 237.60

There is due the Association:

Specifications	$2.10
Advertisements	36.25
Journal	1.00
	$39.35

There are no outstanding bills against the Association.

WILLARD KENT, *Secretary*

The Editor, Mr. Richard K. Hale, submitted the following report:

Report of the Editor.

Boston, January 11, 1911.

To the New England Water Works Association, — I present the following report as editor of the Journal of the New England Water Works Association for the year 1910.

The accompanying tabulated statements show in detail the amount of material in the Journal; the receipts and expenditures on account of the Journal for the past year (including the cost of the December Journal and reprints, bills for which were received too late to pay in 1910, and which are consequently not included in the Secretary's and Treasurer's statements); and a comparison with the conditions of preceding years.

Size of Volume. — The volume is considerably larger in total pages and pages of text than that of any preceding year.

Illustrations. — The total cost of illustrations for the year, including printing, has been $127.11, or 3.7 per cent. of the gross cost of the volume.

Reprints. — The usual fifty reprints of papers have been furnished to authors without charge. There have been no advance copies of papers prepared during the year. The net cost to the Association for reprints and advance copies has been $143.74 (assuming that the December reprints chargeable to members are promptly paid for).

Circulation. — The present circulation of the Journal is:

Members, all grades	747
Subscribers	56
Exchanges	24
Total	827

an increase of 25 over the preceding year.

Advertisements. — The December issue contained 27 pages of paid advertising, which, if maintained throughout the year, would mean an annual income from this source of $1 870. A year ago the figures were 23½ pages and $1 640, showing considerable increase during the year.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $43.55 have been sold. Five hundred copies have been printed, at a cost of $27.50, representing a net gain of $16.05 for the year. The net gain up to a year ago had been $191.20, so that the total net gain from this source to date is $207.25. There are still about one hundred and forty-eight copies of specifications on hand, or about $14.80 worth if sold at retail.

The Association has a credit of $0.98 at the Boston Post-office, being the balance of the money deposited for payment of postage upon the Journal at

pound rates. There are no outstanding bills against the Association on account of the JOURNAL, which are not included in these tables.

Respectfully submitted,

RICHARD K. HALE, *Editor.*

TABLE No. 1.

STATEMENT OF MATERIAL IN VOLUME XXIV, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1910.

Number.	Date.	Pages of									Total Cuts.
		Papers.	Proceedings.	Total Text.	Membership.	Index.	Advertisements.	Cover and Contents.	Inset Plates.	Total.	
5	March	220	38	258	—	–	27	4	1	290	1
2	June	73	13	86	—	–	30	4	2	122	6
3	September . . .	71	3	74	2	–	30	4	9	119	19
4	December . . .	204	21	225	2	8	32	4	6	277	12
	Total . . .	568	75	643	4	8	119	16	18	808	38

TABLE No. 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XXIV, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1910.

Receipts.		*Expenditures.*	
From advertisements . .	$1 750.00	For printing JOURNAL . .	$2 354.71
From sale of JOURNAL . .	204.50	For preparing illustrations,	79.36
From sale of reprints . .	34.25	For editor's salary . . .	300.00
Subscriptions	168.00	For editor's incidentals .	30.70
	$2 156.75	For advertising agent's commissions	250.00
Net cost of JOURNAL . .	1 334.06	For advertising incidentals,	7.25
		For reporting	290.80
		For reprints	177.99
	$3 490.81		$3 490.81

TABLE No. 3.

Comparison between Volumes XVI to XXIV inclusive, Journal of the New England Water Works Association.

	Vol. XVI. 1902.	Vol. XVII. 1903.	Vol. XVIII. 1904.	Vol. XIX. 1905.	Vol. XX. 1906.	Vol. XXI. 1907.	Vol. XXII. 1908.	Vol. XXIII. 1909.	Vol. XXIV. 1910.
Average edition (copies printed),	1 200	1 200	900	900	900	1 085	1 000	1 000	1 150
Average membership	571	587	596	625	665	693	699	710	732
Circulation at end of year . .	648*	656*	667	705	767	785	780	802	827
Pages of text	403	430	491	587	495	500	500	459	643
Pages of text per 1 000 members	707	733	824	939	745	722	715	646	880
Total pages, all kinds	584	619	794	784	662	669	681	627	808
Total pages per 1 000 members,	1 020	1 051	1 332	1 254	995	964	976	884	1 090
Gross Cost:									
Total	$2 439.99	$2 706.05	$2 928.77	$3 266.65	$2 573.61	$2 643.42	$2 733.61	$3 111.15	$3 490.81
Per page	4.18	4.38	3.69	4.17	3.88	3.95	4.01	4.97	4.32
Per member	4.27	4.61	4.91	5.23	3.87	3.82	3.91	4.39	4.78
Per member per 1 000 pages,	7.32	7.46	6.18	6.67	5.85	5.70	5.88	7.00	5.90
Per member per 1 000 pp. text	10.60	10.72	10.00	8.91	7.81	7.62	8.02	9.56	7.44
Net Cost:									
Total	$622.89	$770.62	$648.11	$1 072.95	$387.96	$483.15	$131.06	$789.98	$1 334 06
Per page	1.07	1.25	.82	1.37	.58	.72	.19	1.26	1.65
Per member	1.09	1.31	1.09	1.72	.58	.70	.19	1.11	1.82
Per member per 1 000 pages,	1.87	2.12	1.30	2.20	.88	1.04	.28	1.78	2.25
Per member per 1 000 pp. text	2.71	3.05	2.22	2.93	1.18	1.39	.39	2.43	2.83

* Exclusive of three hundred sample copies.

Report of Auditing Committee.

Boston, January 11, 1911.

We have examined the accounts of the Secretary and Treasurer of the New England Water Works Association, and find the books correctly kept and the various expenditures of the past year supported by duly approved vouchers.

While the gross income has shown an increase of some twelve hundred dollars, the expenditures have increased in a still greater ratio, and the assets of the Association show a decrease of about seven hundred dollars.

Respectfully submitted,

JOHN C. CHASE,
GEORGE H. FINNERAN,
Auditing Committee.

On motion of Mr. Stacy, it was voted that the reports of the Secretary, Treasurer, Editor, and Auditing Committee be accepted, placed on file, and printed.

Mr. Charles W. Sherman, chairman, presented a report from the committee "on information as to the conditions under which extensions of water mains are made by town-owned water supplies."

On motion of Mr. Bancroft, it was voted to accept the report and to discharge the committee.

Mr. King, the retiring President, at this point made his annual address.

President's Address.

Members of the New England Water Works Association:

Gentlemen, — At this meeting you expect and are entitled to receive from your officers a record of their stewardship. This has been given you. Reference to a few matters may be pertinent.

Our membership has increased in numbers 32 during the year, — a gain of 1 in the associate list and 31 in the active list. The balance is on the right side, and therefore we may take a hopeful view of the condition; but a gain of 5 per cent. annually is not what it should be. It can be increased only by *individual* effort.

The report of receipts and expenditures shows a draft on our surplus to pay current expenses. The overdraft will be greatly reduced when a balance sheet is struck off after the issue of the December Journal, the cost and receipts for which justly belong in the accounts of 1910.

This association has, during the year, been in conference with other organizations in several important matters.

We were invited to be represented by a delegate in the Boston-1915 Movement, and Vice-President McInness was selected for the position.

The movement for erecting a building for the headquarters of the various scientific and technical societies in Boston received fresh impetus early in the year and, under the leadership of Professor Hollis, representing the Mechanical Engineers, has continued its activities throughout the year. Vice-President Metcalf is our representative on the general committee.

A conference on "Uniform Accounting for Water Works" was held at Washington in May, at which this association was represented by its President. A report was agreed upon which has not been published. The final draft of the report was left in the hands of a committee, and it is understood that they are revising certain technical features. The result of this conference will probably tend to bring the various state authorities to more uniform methods in their demands for accounting by the different works under their jurisdiction.

Delegates were appointed to represent this Association at the Conservation Congress at St. Paul, and their report was given at the annual convention in Rochester.

The success of the special meeting in Hartford in April may be largely attributed to the work of the local members. It was an experiment worthy of repetition.

In one matter I was unable to convince the Executive Committee of the desirability of a change I advocated. Being strongly convinced of the soundness of my position, I wish to make it a matter of record. An organization, with members scattered all over the world, and seven hundred in number, doing a publishing business of $3 000 per year, should, I believe, be incorporated.

I wish to express here my deep appreciation of the loyal, efficient work of the members of the Executive Committee and to acknowledge that to them belongs the credit for any measure of success attained during the year, also to express my thanks to the members of the Association for their many kindnesses.

Early in the year I conceived the idea of collecting data, hoping

at this time I might interest you by giving a glimpse into the field of water-works activities in 1910.

It can be but a glimpse, as time would not permit to give even a list of the places where new systems are being constructed, where radical and extensive changes in old works are being made, where high-pressure fire systems are being planned, where larger pumping plants are being installed, where a revision of rates is being agitated, where a more complete system of metering is demanded, and where purer water through some method of sterilization or filtration is a necessity which is being cared for. The wealth of material makes the labor of eliminating enough to bring this address within the time at our disposal a most difficult task. Only the largest undertakings and those of the best-known localities can be mentioned unless some special feature seems to demand it. The material here presented is from printed articles in engineering and technical literature, and is not given from first-hand information. Conflicting articles have prevented the use of some material. With these general statements let us turn to some of the work going on abroad.

In the early part of the year the Prince of Wales (now King George) turned on the additional sources of water supply which marked the completion of the Vrynwy water scheme for Liverpool and the suburban district of 215 sq. miles outside the city.

The scheme was sanctioned by Parliament in 1880. To carry it out, villages, schools, and churches had to be demolished, and their site submerged some 80 ft. A reservoir was built containing more than 12 thousand million gallons. An aqueduct 68 miles long was constructed, and mountains have been tunneled to bring the water of two other valleys to this reservoir. The total cost has been £3 000 000.

London is just completing a reservoir for storage of water from the river Lea. The reservoir is two thirds of a mile wide and a mile and two-thirds long, and to guard against damage by large waves it is divided into two sections by a wall. The bed of the reservoir is in clay and the sides lined partly with brick and partly with cement. It cost $2 750 000. London has 62 other reservoirs with capacity of 8 913 million gallons which will supply the city 39 days. The new reservoir will add 13 days' supply.

The Metropolitan Water Board of London will ask sanction of Parliament for a scheme to provide a series of reservoirs in the Thames Valley. It will require twenty years for their construction and they will cost $55 000 000.

Works which have cost $20 000 000 were recently opened in Vienna by the Emperor Francis Joseph with impressive ceremonies. The supply is brought 100 miles, from "delicious Alpine springs" at a height of 6 000 ft. above the sea. It requires forty-eight hours for the water to reach the city. Vienna claims it has the best water supply in the world.

In Granada the old system of water supply, which through neglect has long refused to work, has been repaired under Senor Crudaye, an architect, and the famous fountains in the Alhambra are playing again.

Jerusalem, with 80 000 inhabitants, depends almost entirely on rain for water supply, which is about 27 in., and this is stored on roofs in cisterns. Various efforts have been made since King Solomon's time to secure a supply for the city. There are three reservoirs known as Solomon's Pools about seven and one-half miles nearly south of the city, which will hold 3 000 000 gallons of water. These are filled with water from the hills in rainy weather. From these pools a masonry aqueduct built by King Solomon carried water to the temple at Jerusalem; at one point it runs through a mountain in a tunnel. In the sixteenth century this was remodeled by Mohammedans.

In the second century the Romans had an ambitious scheme to bring water through an aqueduct some 20 miles long, but seemed unable to finish it. In 1901, the authorities, aroused by serious shortage, repaired King Solomon's aqueduct, using iron pipe in places. The supply is but a trifle to the city's need. Parliament, in Constantinople, granted the municipality a right to appropriate hides of all animals slaughtered in Jerusalem as a tax to produce a fund with which a water supply could be secured. The city proposes to make a large loan and to repay it by this tax and receipts for water. A Bremen firm has made a proposition, now under consideration by a committee of the city government, to pump Ain Farrah water into Jerusalem, piping each house and charging for same 1.25 francs (about 24 cents) per cubic meter.

To any one paying in advance 1 500 francs, they offer to furnish one cubic meter per day for thirty years. About 75 cu. m. are allowed to the city free and the balance at half price. The whole work is to become the property of the city in thirty years.

An elevated reservoir has been under construction at Calcutta. The city has been supplied by direct pumping. There was difficulty in designing a reservoir as it must rest on the crust of earth not more than 20 ft. thick underlaid by soft silt and must be built to resist earthquakes, although these are not very severe there. The reservoir built is a steel tank 320 ft. square, 16 ft. deep, and raised 90 ft. above the ground on steel columns. The column footings consist of a reinforced concrete bed 340 ft. square and 2.5 ft. thick; in some places short piles were driven. The structure and contents weigh about 70 000 tons, or a pressure of about 1 200 lb. per square foot.

Pekin's 600 000 inhabitants, until the present year, never had a public water supply. Since the foundation of the city in the thirteenth century, they have depended on private wells, which for many years have been fertile sources of disease.

A few months ago a local company of Chinese got together a capital of $2 000 000, and city works were built. Water is obtained from a mountain stream 10 miles northeast of Pekin. It is carried to settling tanks, then filtered through river sand and finally pumped to three city reservoirs with combined capacity of 1 200 000 gal. The daily capacity of the plant is 3 500 000 gal. A curious method of delivery is in use; the water runs from a water tower to 420 street hydrants, each manned by a coolie, where it is retailed at so much per quart or gallon.

Twenty progressive consumers have had pipes carried directly to their premises, where meters are installed. The rate is 20 cents per 1 000 gal. The company is now endeavoring to popularize bathing, to increase the trade in water.

An increased supply of water for Honolulu has been obtained by the building of the largest dam on the island at a cost of $300 000. The new dam, which is known as the Nuaun, will impound enough water for many months' supply for the city.

At the celebration of the Mexican Centennial of Independence on September 21, in the presence of a large gathering of officials

and guests, a new water system for Mexico City was inaugurated.

An additional supply for Vancouver, B. C., was necessitated by the rapid increase of population. Water will be taken from Seymour Creek, 7 miles above its mouth, at an elevation of 465 ft. above the sea. The pipe line has four and one-third miles of 30-in. and 36-in. wood stave pipe and the rest is made of lap welded steel pipe. A distribution reservoir of 24 000 000 gal. capacity will be built at an elevation of 395 ft. above the sea. The bottom and side slopes are to be of concrete.

The Pacific coast of our country has been the scene of unusual activity in water-works matters. The Los Angeles project, probably exceeded in magnitude by only one other in the world, has been pushed and is now nearing completion. Little of the work is done by contract but is done by the men employed directly by the city. Early in the year a delay was occasioned by a failure in the furnishing of money by the sale of the bonds, and nearly the entire force was laid off for a time.

We get but a faint idea of the magnitude of this scheme when we are told that 240 miles of aqueduct are to be built at a cost of $24 500 000, and that an estimate of the quantity to be obtained is 260 million gallons per day. Some of the items help us in our attempt to conceive its vastness. Five thousand men have been employed upon the work this year, 80 000 acres of land have been bought, 500 buildings have been erected, 240 miles of telephone and 230 miles of road constructed. A cement mill has been equipped, capable of turning out 1 000 barrels per day. The Southern Pacific has a contract to convey 20 000 000 ton-miles. The courage and confidence in their future is manifest in the vote of the city endorsing the scheme, which was virtually to tax themselves $88 per capita. The vote stood 21 918 in favor and only 2 128 against the project.

San Francisco, on January 14, 1910, voted on two propositions for a water supply which would lead to a change from private to municipal ownership of system. The vote was by a large majority in favor of the Hetch Hetchy project. The permission granted the city for the use of this valley by former Secretary of Interior Garfield has been suspended and final decision postponed until

May 1, 1911. Meantime measures looking to a compromise so that the city may buy the Spring Valley Water Company property are under consideration.

A proposition of the People's Water Company to sell its entire holdings to the city of Oakland, Cal., for $18 500 000 has been before the city council of that city. The district served by this company includes Oakland, Berkeley, Alameda, Richmond, Pinola, San Pablo, San Leandro, and several smaller towns. The above proposition has stirred to vigorous action a rival company, the Bay Cities' Water Company. Fifty canvassers have been at work for the latter company, and the people are said to be signing contracts for the water by the thousands, and the water problem for the east side of San Francisco Bay is said to be solved.

At Seattle, Wash., improvements are in construction, with others in contemplation. Seattle expects to secure as large a supply of pure water as Los Angeles at about one third the cost.

At Portland, Ore., a third water main under the Willamette River is about to be laid which will increase the city's supply by 50 000 000 gal. per day, at a cost of $125 000.

The question of a municipal supply for Denver, Colo., is agitating that city. The Denver Union Water Company ask $14 400 000, the appraised value, for their plant which the public utilities commission says is worth but $6 405 000. The voting taxpayers have refused a renewal of the franchise of the company. A suit has been filed in the interest of the company in the United States District Court asking an injunction to restrain the city from holding an election to authorize an $8 000 000 bond issue for the construction of new works.

After eight years of litigation, Omaha, Neb., has voted to buy the works of the Omaha Water Company at the valuation of the appraisers. Its vote has been sustained by the court, and the company must accept the amount of the appraisal, $6 263 295, although the company's stock and bonds represent $11 750 000.

Work upon the intake tunnel for the Buffalo Water Works, begun some three years ago, has continued and is nearing completion. This tunnel is about 11 000 ft. long. Buffalo has spent upwards of $3 000 000 in the improvement of the works.

Baltimore, Md., has adopted a plan of improving her water

supply at an estimated cost of $6 630 000. A new reservoir is to be built in Gunpowder Valley. Coagulating and settling basins will be built and used with sand filtration.

The biggest water-works scheme in the world is that under construction for Greater New York. This project was organized in 1905, but construction work was not begun until February, 1908. Briefly, the project is to impound water in the valleys near the Catskill Mountains and bring it about 92 miles to New York at a cost of $162 000 000. It is expected the supply will be 500 million gallons per day. The impounding dam, known as the Olive Bridge dam, is being built and is said to be second in size in the world. It will impound 127 thousand million gallons. About one half of the work on this project is now under contract. The Ashokan Reservoir on the Esopus Creek is now under construction. It will be 12 miles long and one to two miles wide.

In this scheme there are 35.4 miles of pressure tunnels and 13.8 of gradient tunnels. Work is in progress upon several of these tunnels. At one of them, the Wallkill, the contractors have established a hospital to accommodate 18 patients and employ a resident surgeon. There are said to be 11 000 men at work upon the whole scheme and 270 policemen are employed for the protection of persons and property.

In connection with this scheme a deep rock pressure tunnel for the distribution of the water to various parts of Greater New York has been adopted. This tunnel, as planned, will be 17.5 miles long and 200 ft. below the surface of the street. It will cost from $25 000 000 to $50 000 000. Contracts are about to be executed for this work.

We would belie our name if no New England work was mentioned. Pittsfield, Mass., has authorized an extension of the system of suppy to cost $500 000. A stone and concrete dam will be built to store 440 000 000 gal.

Springfield, Mass., early in the year began to use the water of their new supply taken from the Little River in Westfield.

Portland, Me., is rebuilding its works. The contract has been let for laying 14 miles of main. The cost will be nearly $1 000 000. The contractor is said to be using machinery in excavating for the pipe trenches.

Power and Pumps.

We note almost innumerable instances of pumping plants undergoing changes and having additions made to them. Frequent mention is made of gas-producer plants, gas engines, and electric-driven pumps. The latter is not confined to the smaller pumps, twelve million gal. daily are pumped with electric pumps in Duluth and one of 20 000 000 gal. capacity is recommended for Minneapolis. Gas-producer plants have been rapidly increasing in number and in amount of power produced. During 1909, their power was nearly doubled and the number of plants increased 70 per cent. The same increase for 1910 is probable. The steam turbine is being widely used.

An engine advocated as a valuable auxiliary of the steam turbine is the rotary. Several working models of these engines have attracted considerable attention during the year, and their inventors claim that they have perfected a practical engine. For more than one hundred and twenty-five years inventors have attempted to build a successful engine of this type and it is said that Westinghouse has spent three quarters of a million dollars in the endeavor to produce one. Tests have recently been made with rotary engines of 20 h.p. to 25 h.p. with gratifying results. Whether engines of large horse-power of this type can be built, remains to be developed. Some of the advantages claimed for this type are the small space they occupy and the small amount of vibration as well as economy of power.

Tanks.

Reinforced concrete is being more and more used in building tanks and standpipes. The pictures of those being built emphasize the variety of forms which this material allows. We find the plain round tank whose bottom is on the ground and which has an open top and the tank on concrete pillars 112 ft. high which has a concrete roof. Concrete reservoirs, both open and covered, are being built all over the country. The Southern Pacific Railroad are building tanks to hold 60 000 gal. These have a bottom supported by a dome built of reinforced concrete.

At Syracuse, a handsome standpipe of steel with an outside

protecting wall of vitrified brick and artificial stone has been built.

High-Pressure Systems.

An emergency high-pressure service has been put in operation at Jacksonville, Ga. It has five miles of mains from 8 in. to 20 in. in diameter. It uses electric motor driven pumps.

Oakland, Cal., has completed a salt-water fire protection system giving a pressure of 150 lb. per square inch at hose nozzles. The part of the system now built encircles seventy blocks in the business district.

The high-pressure fire main service has been extended in the northeast or mill section of Philadelphia. The mains are from 10 in. to 20 in. in diameter and there will be 300 lb. working pressure when in service. This system is claimed to be the most complete and powerful fire-fighting apparatus in the world. It is estimated to cost $2 000 000.

Camden, N. J., has authorized the issuing of bonds to the amount of $400 000 for an auxiliary water plant for fire and commercial purposes.

Cleveland, Ohio, is considering the installation of a high-pressure pumping station. High-pressure mains have already been laid which are supplied with water by tug boats. Toledo, Ohio, Joliet and Bloomington, Ill., are considering the installation of high-pressure mains for fire protection, and extensive additions are being demanded in Boston, Mass.

Six hundred thousand dollars is being spent in Baltimore, Md., for a high-pressure fire system capable of supplying 29 000 gal. per minute. It is designed so as to take its supply either from the city's mains or from the river, the latter to be used in an emergency. The mains are lap welded, soft, open hearth, steel pipe. It is usually laid in 20-ft. lengths, although one piece of 10-in. pipe 117 ft. long has been laid.

Electrolysis.

Troubles from electrolysis have not been reported during the year to any great extent.

It is reported that in Houston, Tex., large mains in the business section have been replaced as they have been destroyed by the

underground currents of electricity. Mention is made of similar trouble at Elyria, Ohio, and Tusla, Okla.

A suit for an injunction to prevent the Central Railway Company of Peoria, Ill., injuring by electric currents the property of the Peoria Water Works Company, has been tried and the verdict rendered. The master's report indicated a complete victory for the water company. The master's report was not sustained by Judge Sanborn of the United States Circuit Court. The decision of the judge, while in a way a compromise, seems to favor the street railway rather than the water company.

Meters.

It is reported that in one of our large cities where meters are being extensively installed some large increases have been noticed in water bills. Two cases are cited, in each of which an annual flat rate charge of $16.50 had been collected. After metering, in one case the charge for three months was $57.60, and in the other for the same period $96. One real estate owner was so indignant over the increase that she ordered the water shut off and the buildings torn down.

The desirability of installing meters is being considered in a large majority of the municipally owned works not now metered.

Scranton people are happy in the fact that they have not suffered from shortage of water, and attribute it to the saving occasioned by the use of meters. A suit in this city to recover for a bill for metered water was contested on the ground that the bill was too large and that the meter was "working double." The water company proved the accuracy of its meter and obtained a verdict in its favor.

At Houston, Tex., a reduction in rates of 50 per cent., and the probability of another reduction soon, is attributed to the use of meters.

The largest claim noted of the benefit to be obtained from the use of meters is the reported statement of a prominent engineer to one of our large cities that the water consumption would be decreased 100 per cent. by the use of meters. It is a fair statement that meters "protect the innocent, punish the offender, lessen the cost of operating the plant, and conserve the water supply."

Rates.

A spirit of unrest seems to prevail all over the country in regard to proper rates for use of water. The methods employed to determine rates are varied and some are unique. The tendency, as stated, is very general toward meterage. For metered water, prices have been quoted during the year from two to forty cents per thousand gallons. Hydrant rentals paid private companies are from $2.50 per hydrant, in San Francisco, to $65 for the first 100 hydrants and $50 for the balance, in Vicksburg, Miss. With the advent of total meterage will come more scientific methods of determining rates. The decisions of the Wisconsin Railroad Commission, which is practically a public utility commission, and the methods used by it, are forerunners of what may soon prevail in all the states. Its decision in the case of the Ripon Light and Water Company is worthy of study.

Collection of Rates.

We note that in two instances the plan of shutting off the supply of delinquents has been forbidden by boards of health on sanitary grounds.

Waukegan, Ill., water department will post the names of delinquents of two years' standing.

Consumption.

The conditions in different places vary so largely that without full knowledge we cannot make fair comparisons. We notice two cities claiming the largest consumption in the United States: Ann Arbor, Mich., with the amount not given; and Spokane, Wash., with a consumption of 289 gal. per capita per day. The latter claim also to be furnishing water cheaper than any city in the United States.

The consumption of Buffalo, N. Y., is reported as 300 gal. per day.

Care of Watershed.

When asked if the water of certain springs was pure, an old negro replied, " Yessum. Dis yar water has been scandalized by de best phrunologers in de lan', and dey say, dey do, as how it

muntain ten parts er oxhide acid, ten parts er cowbonic acid, and de balance am clar hydrophobia — Yessum." To secure this pure water is one of the great problems of the day.

More and more attention is being paid to the sanitary conditions of the watersheds. On many of them inspectors are constantly patrolling, and on some, land purchases are being made. We notice Newark, N. J., has paid $52 000 for one tract of 328 acres, and $12 000 for another of 600 acres. We note that a judge has refused the application of a party desiring to keep a hotel on this watershed. Improvements on the watershed of the supply of Mt. Vernon, N. Y., are demanded. North Adams, Mass., has appropriated $20 000 for purchasing land on the watershed of its supply. Rochester, N. Y., has procured about all the land about Lake Canadice. Atlantic City has expended more than $350 000 in securing the watershed of its supply and has purchased over 6 000 acres. In many instances, the care of the watershed is insufficient and some means of treating the water becomes necessary.

Filtration.

The old method of sand filtration is still being installed, even outside of Massachusetts. It is frequently supplemented by some chemical as coagulant or sterilizer being introduced prior to the filtration. This method is proposed for Baltimore. Sixteen sand filters are in process of construction for Reading, Pa. Niagara Falls, N. Y., will use sand filters to filter 15 000 000 gal. per day. Sand filters are under construction for Toronto whose daily capacity will be 35 000 000 gal.

Hypochlorite of lime is being much used in water sterilization. Omaha, Neb., began its use early in 1910 and is sterilizing 27 000-000 gal. daily. It is about to be tried if not already in use in Kansas City, Mo.; Milwaukee, Wis.; Bridgeport, Conn.; and for part of the Croton supply for New York.

Mechanical filtration is being installed in many places, among them is Bangor, Me.; Atlanta, Ga.; Rock Island, Ill.; and Montreal, Quebec. Newport, R. I., has just completed a plant. Whether or not this system will be installed in Lynn, Mass., is still undecided.

Ozone.

The use of ozone for water sterilization still continues. It seems to be successfully used in France. At Nice they have completed two plants with a total capacity of 10 000 000 gal. per day and have another under construction. As the ozone is produced by electricity, the process is frequently mentioned as an electric treatment. The failure of this treatment at Lindsay, Ont., seems to have been due to the fact that the ozone and water were not properly mingled, and not from failure to produce ozone. An experiment at Ogdensburg, N. Y., failed to remove the color of the water.

An ozone sterilization plant for treating daily 10 000 000 gal. filtered water from the River Marne (a highly polluted stream) is under consideration for Paris. It is said the cost of treatment has been $6.67 per 1 000 000 gal.

Ultra-Violet Rays.

Some very interesting laboratory experiments with ultra-violet rays from a quartz-tube mercury arc lamp have been made in Paris. The use of these rays for such purposes has been known since 1877, but only recently has their use been attempted for disinfection of water in any large quantities. These experiments show that their use begins to look feasible. About a year ago, the city of Marseilles opened a competition to various mechanical filtration concerns. At the end of the tests, the city proposed to decide which method it would adopt for purification of its water supply. Each company was required to install, at its own expense, a plant of sufficient size to purify 52 840 gal. of water every twenty-four hours. As a result of this test, the ultra-violet ray system, with a preliminary treatment through roughing filters, was accepted. In the apparatus used, the water was required to pass the lamp three times. The cost of sterilization was about $10 per million gallons, and in 8 tests where an aggregate of 1 700 B. coli per liter were found before treatment, none were found after, and 98.3 per cent. of other bacilli were removed. Cleveland, Ohio, is considering a trial of this method.

Filtration plants at Wilmington, N. C.; Grand Rapids, Mich.;

and Minneapolis, Minn., are under construction, and Toledo, Ohio, has but recently put one in operation. The plant at Wilmington, Del., is stated to be the " most up-to-date filtration plant in the world."

At the city of Farlington, England, the Portsmouth Water Company have a slow sand filtration plant in which the filters are in part located on top of the storage reservoir.

It may not be out of place to here mention that the Supreme Court of Minnesota has just handed down a decision in which it holds that municipalities in that state are liable in damage suits for the death of citizens who contract disease through drinking polluted city water.

Several large claims have been in litigation for alleged unlawful taking of water. A decision in the case against the American Sugar Refining Company for stealing water at its Williamsburg plant has been rendered by Judge O'Brien, the referee. He awarded the city $525 000 and costs.

The National Lead and Oil Company is accused of taking water to the value of $60 000 from the Water Company at Parnassus, Pa. Suit has been entered to recover the above, with damages set at $100 000.

In Philadelphia, the high-pressure mains have been unlawfully tapped and one property owner has settled for $3 000.

Accidents.

It would seem to the writer that in the past year there had been an unusually large number of breaks in big mains, and breaks that have done serious damage.

The breakage of a five-foot main threw 3 000 men out of work and did property damage to amount of $75 000, beside cutting off a town's supply for several days.

The breaking of a main in one city threw paving blocks as high as the house tops, and another city lost 8 500 000 gal. of water. In another city the breaking of the water main broke the gas main and filled it with water and sand.

Asheville, N. C., had its supply main crushed by the fall of a big tree. Akron, Ohio, had a strange accident befall its works.

By the breaking ot a brick sewer, the sewer was plugged and the sewage overflowed from a manhole, ran down a hill a distance of more than one fourth of a mile, and flooded Summit Lake, the city's source of supply. The lake had to be drained.

Corona, Cal., has had its water supply materially increased as the result of an earthquake.

Among the water items noted are, — that the divining rod and hydroscope are still used in searches for water supplies; that the women of Saginaw, Mich., to the number of 1 657, registered to vote upon the question of issuing bonds to the amount of $400 000, to build a water and filtration plant for the city.

An unusual memorial is a system of water works, but the town of Thornton, Ind., has the distinction of having one.

The entire system was the gift of Gen. Anson Mills, in memory of his father and mother. Water is raised from a 110-ft. well by an air-lift system, and delivered to a 20 000-gal. underground concrete reservoir. A turbine centrifugal pump raises it to a steel 40 000-gal. tower, 80 ft. high. The machinery is operated by electricity.

We have spoken of the large number of places in which construction has been in process in 1910. In the ordinary course of affairs, one would naturally expect greater activity the coming year. The great drought which has prevailed over such a large extent of our country is likely to cause an unusual amount of engineering and constructing work in 1911.

Let me close with this sentiment for the New England Water Works Association in 1911, —

May it be the best year it has ever known, and the worst it will ever know.

Election of Officers.

Mr. Charles W. Sherman submitted the following report of the tellers appointed to canvass ballots.

President.

Allen Hazen	316	Scattering	4

Vice-Presidents.

J. WALDO SMITH	286	MORRIS KNOWLES	197
LEONARD METCALF	286	ERMON M. PECK	147
MICHAEL F. COLLINS	278	GEORGE H. SNELL	107
IRVING S. WOOD	273	SAMUEL P. SENIOR	78
FRANK A. MCINNESS	261		

Secretary.

WILLARD KENT 324

Treasurer.

L. M. BANCROFT 320

Editor.

RICHARD K. HALE 327

Advertising Agent.

R. J. THOMAS	327	Scattering	1

Additional Members of Executive Committee.

EDWIN A. FISHER	293	WILLIAM E. MAYBURY	266
JOHN J. KIRKPATRICK	287	OREN E. PARKS	119

Finance Committee.

A. L. SAWYER	311	JOHN H. WALSH	247
GEORGE H. FINNERAN	285	WILLIAM E. MAYBURY	109

The President thereupon declared the following-named gentlemen to have been elected officers for the ensuing year: President, Allen Hazen; Vice-Presidents, J. Waldo Smith, Leonard Metcalf, M. F. Collins, F. A. McInness, I. S. Wood, and Morris Knowles; Secretary, Willard Kent; Treasurer, L. M. Bancroft; Editor, R. K. Hale; Advertising Agent, R. J. Thomas; additional members of the Executive Committee, W. E. Maybury, E. A. Fisher, J. J. Kirkpatrick; Finance Committee, G. H. Finneran, A. L. Sawyer, and J. H. Walsh. He then presented Mr. Hazen, who spoke as follows:

Gentlemen, Fellow-Members of the New England Water Works Association: I feel very deeply the honor that you have conferred

upon me. I feel it more deeply because I believe that I am the first non-resident member who has ever been elected to this proud office. I looked yesterday through the list of my illustrious predecessors, twenty-eight of them, one for each year of the Association's work. They have been and are representative men, leaders, men who have led the Association in its work to some purpose, and I am proud to have my name added to the list.

I began my professional work in Boston. My shingle was hung out at 85 Water Street, where our editor now holds out. The work went well during those first two years in partnership with Mr. Noyes, who was elected President of this Association twenty years ago. It went well largely because of the wide acquaintance which Mr. Noyes had, and the universal respect and esteem in which he was held. Afterwards, finding myself alone in the world, and having found out something of the character of the New England Water Works men, I saw that they were too far along in the game to be fooled very long. [*Laughter.*] I knew it would only be a matter of a short time when they would find out how little I really knew about water works. [*Laughter.*] So I looked around for some place where the game was easier, and I moved to New York. [*Laughter.*] Fifteen years afterward, I have only kind words to say of New York, but I want to say to you that I appreciate, more than I can tell, the many, many times that I have been called back to the home field to help you in your problems, and I appreciate very much indeed what you have done for me to-day in conferring upon me the great honor that you can give. [*Applause.*]

Mr. Chase. Mr. President, I do not think it is ordinarily the thing to thank an official for doing his duty, but when he goes beyond it, I think there should be some notice taken of it. I think, therefore, that the thanks of this Association are due to the retiring President for the very able, exhaustive, and instructive address he has given us on the water-works engineering conditions in the country and in the world in the past year, and I move that our thanks be tendered to him for his address. [*Applause.*]

The motion was put by Mr. Hazen and was enthusiastically carried.

Adjourned

February Meeting.

Hotel Brunswick,
Boston, February 8, 1911.

The President, Allen Hazen, in the chair.
The following members and guests were present:

Honorary Member.

Frederic P. Stearns.

Members.

S. A. Agnew, Kenneth Allen, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, G. W. Batchelder, F. D. Berry, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, George Bowers, E. C. Brooks, G. A. P. Bucknam, James Burnie, G. A. Carpenter, J. C. Chase, R. D. Chase, M. F. Collins, E. D. Eldridge, A. N. French, A. D. Fuller, F. L. Fuller, Albert S. Glover, J. M. Goodell, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, L. M. Hastings, Allen Hazen, E. W. Kent, Willard Kent, F. C. Kimball, G. A. King, J. J. Kirkpatrick, Morris Knowles, E. E. Lochridge, H. P. T. Matte, N. A. McMillen, A. E. Martin, H. A. Miller, F. L. Northrop, E. M. Peck, T. A. Peirce, Henry Roberts, A. L. Sawyer, W. H. Sears, J. E. Sheldon, J. Waldo Smith, W. F. Sullivan, C. N. Taylor, H. L. Thomas, R. J. Thomas, W. H. Thomas, J. L. Tighe, E. J. Titcomb, J. A. Tilden, W. H. Vaughn, G. E. Winslow, H. B. Wood. — 60.

Associates.

Anderson Coupling Company, by C. E. Pratt; Builders Iron Foundry Company, by A. B. Coulters and George H. Lewis; Chapman Valve Manufacturing Company, by H. L. Dewolfe; Darling Pump and Manufacturing Company (Ltd.), by H. H. Davis; The Fairbanks Company, by W. D. Cashin; Platt Iron Works Company, by F. H. Hayes; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden and W. A. Hersey; Henry R. Worthington, by E. F. Nye; Lead Lined Iron Pipe Company, by T. W. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin, H. L. Weston, and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Valve Company, by F. S. Bates; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall; Water Works Equipment Company, by W. H. Van Winkle. — 24.

Guests.

G. H. Abbott, treasurer Water Company, Southbridge, Mass.; I. S. Holbrook, *Engineering Record*, Clarence Goldsmith, E. T. Jonson, New York City; George W. Bowers, Lowell, Mass.; Anthony Flemming, John D. Hanachan, J. J. Desmond, Lawrence, Mass.; Frank Collins, White River Junction, Vt.; E. W. Priest, J. W. Mackenzie, Mansfield, Mass.; and C. E. Batchelder, Boston, Mass. — 12.

The President. It is my sad duty to announce the death of one of our members, Professor Kinnicutt. He had been a member of the Association for some eighteen years, and was a man whom we have all known and loved, a man of great unselfishness, always working for the benefit of those about him and for the cause. The Association has suffered a great loss in his death.

The Secretary then presented applications for membership from the following-named persons, all properly recommended, and approved by the Executive Committee: Joseph N. McKernan, Plainville Conn., member Plainville Water Board; Clarence Goldsmith, New York City, hydraulic engineer, National Board of Fire Underwriters; C. Nelson Harrub, Mundale, Mass., resident engineer in charge of the West Parish Filter Plant, Springfield, Mass.; C. H. Abbott, Southbridge, Mass., superintendent and treasurer, Southbridge Water Supply Company; George W. Priest (for associate membership), Mansfield, Mass., president of New Hartford Water Company and of the Composite Pipe Company.

On motion of Mr. Frank L. Fuller, the Secretary was instructed to cast the ballot of the Association in favor of the applicants above named, and he having done so, they were declared elected members.

The President then presented Mr. J. Waldo Smith, chief engineer, who, the program announced, would read a paper on "Construction Work on the Water Supply of New York City." "The New York water supply construction now under way," said the President, "is, I suppose, the largest piece of waterworks construction that has ever been carried out. Certainly that is true of all modern times, and is true, so far as quantities are concerned, even if we go back to the old Roman days, although the Roman aqueducts certainly meant as much to mankind, if

not more than anything undertaken at this time. The work is not only very large, being second only to the Panama Canal work as an engineering enterprise, but it is being prosecuted rapidly and well."

Mr. Smith said he had no paper to present, but had merely come over from New York to show a few pictures and to explain what was being done to furnish an addition to the present supply of the city of New York. He proceeded to give an informal talk illustrated by a large number of stereopticon views.

Mr. Kenneth Allen, chief engineer of the Metropolitan Sewerage Commission, New York, read a paper on "The Use of the Salinometer in Studies of Sewage Disposal by Dilution."

Adjourned.

March Meeting.

Hotel Brunswick,
Boston, Wednesday, March 8.

Vice-President M. F. Collins in the chair.

The following members and guests were present:

Honorary.

Frederic P. Stearns.

Members.

S. A. Agnew, E. R. B. Allardice, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, H. K. Barrows, G. W. Batchelder, A. E. Blackmer, J. W. Blackmer, E. C. Brooks, G. A. P. Bucknam, James Burnie, C. E. Chandler, J. C. Chase. H. W. Clark, R. C. P. Coggeshall, M. F. Collins, L. R. Dunn, E. D. Eldredge, F. L. Fuller, F. J. Gifford, C. W. Gilbert, H. J. Glendenning, A. S. Glover, X. H. Goodnough, R. A. Hale, R. K. Hale, F. E. Hall, J. O. Hamm, L. M. Hastings, A. R. Hathaway, T. G. Hazard, Jr., W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, C. F. Knowlton, Wisner Martin, N. A. McMillen, A. E. Martin, W. E. Maybury, John Mayo, F. E. Merrill, G. F. Merrill, H. A. Miller, C. A. Mixer, William Naylor, A. S. Negus, G. A. Nelson, F. L. Northrop, O. E. Parks. T. A. Peirce, J. H. Perkins, L. C. Robinson, A. T. Safford, H. W. Sanderson, A. L. Sawyer, C. W. Sherman, G. H. Snell, G. A. Stacy, W. F. Sullivan, L. A. Taylor, L. D. Thorpe, J. L. Tighe, D. N. Tower, C. H. Turner, W. H. Vaughn, C. K. Walker, H. G. Holden, G. F. West, F. B. Wilkins, G. E. Winslow. — 72.

Associates.

Builders Iron Foundry, by George H. Lewis; Chapman Valve Manufacturing Company, by H. L. DeWolfe; Darling Pump and Manufacturing Company (Ltd.), by H. H. Davis; Glauber Brass Manufacturing Company, by S. S. Freeman; Hersey Manufacturing Company, by Albert S. Glover, and W. A. Hersey; Henry R. Worthington, by Samuel Harrison; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by S. D. Higley and E. M. Shedd; Union Water Meter Company, by E. P. King and F. E. Hall; United States Cast Iron Pipe and Foundry Company, by D. B. Stokes. — 19.

Guests.

F. W. Dinwiddie, water registrar, Gardner, Mass.; Frank F. Connor, Lowell, Mass.; J. P. Wood, Marlboro, Mass.; Edward Parrish, Asst. U. S. Engineer, Newport, R. I.; John Currier and H. B. Andrews, Boston, Mass.; J. J. Desmond, Lawrence, Mass.; Albert S. Benson, Wm. L. Sharpe, East Greenwich, R. I.; Nathaniel T. Kidder, Milton, Mass.; Edward F. Hughes, Watertown, Mass.; Randolph Bainbridge, Quincy, Mass.; Irving T. Guild, F. W. Rane, and Edward S. Bryant, Mass. Forestry Association, Boston. — 15.

The chairman, on behalf of the Executive Committee, announced that the April meeting would be held at Springfield, Mass. The papers will be on fire protection, both from the point of view of water-works men and practical fire fighters.

The Secretary presented applications for membership from the following, properly endorsed by the Executive Committee:

Active membership: Edwin D. Pingree, Providence, R. I., vice-president and engineer for Manufacturers Mutual Fire Insurance Company; E. P. Stone, Saginaw, Mich., engaged in contracting and dredging work; Boris N. Simin, Moscow, Russia, designer and constructor of water works; J. W. Ledoux, Swarthmore, Pa., water supply, water power, and general hydraulic engineer, and chief engineer for American Pipe and Construction Company; J. L. Van Ornum, St. Louis, Mo., consulting engineer in various sanitary plans in Missouri, and expert in Chicago Drainage Canal cases; Hiram B. Andrews, concrete reservoir and standpipe construction engineer; Rudolph Bainbridge,

Wollaston, Mass., commissioner of public works for the city of Quincy; H. M. Urban, Birmingham, Ala., chief civil engineer, Tennessee Coal, Iron and Railroad Company, in charge of water-works construction and water supply improvement; William L. Wilcox, assistant chief civil engineer, Tennessee Coal, Iron and Railroad Company.

The Secretary was directed to cast the ballot of the Association in favor of the applicants, and he having done so, they were declared elected.

The first paper of the afternoon was on "The New England Portion of the Proposed Atlantic Intra-Coastal Waterways," by Edward Parrish, assistant United States engineer, Newport, R. I., illustrated by stereopticon views. The subject was discussed by Mr. T. G. Harard, Jr., Mr. Frank L. Fuller, and Mr. A. S. Negus.

Mr. F. W. Rane, state forester of Massachusetts, then presented a paper, which was illustrated by stereopticon views, on "The Reforestation of Watersheds for Domestic Supplies." The paper was discussed by E. R. B. Allardice, superintendent of the Wachusett Department, Metropolitan Water Works; E. S. Bryant, practical forester, Boston; Mr. Nathaniel F. Kidder, president of the Massachusetts Forestry Association; Mr. William F. Sullivan, engineer and superintendent, Nashua, N. H.; and Mr. Irving T. Guild, secretary of the Massachusetts Forestry Association.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association, at the rooms of the Association, 715 Tremont Temple, Boston, Mass., Wednesday, January 11, 1911.

Present: President George A. King, and members Allen Hazen, Ermon M. Peck, Michael F. Collins, George A. Stacy, George W. Batchelder, Edwin C. Brooks, Willard Kent, Lewis M. Bancroft, Richard K. Hale, and Robert J. Thomas.

Two applications were received and recommended for admission, namely:

For membership: Henry E. Warren, chairman water commissioners, Ashland, Mass., and A. Lincoln Fellows, consulting engineer, Denver, Colo.

A communication from the local agent of Henry R. Worthington with reference to transfer of associate membership from the International Steam Pump Company was presented, and the Secretary was instructed to communicate with the International Steam Pump Company with reference to same.

The Platt Iron Works Company, having complied with the requirements of the constitution, was, by unanimous vote, reinstated as an Associate.

The committee on annual meeting and the committee on the library submitted their reports and, on motion of Mr. Stacy, the subject of both reports was referred to the next Executive Committee.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., February 8, 1911.

Present: President Allen Hazen, and members J. Waldo Smith, Michael F. Collins, Morris Knowles, John J. Kirkpatrick, Richard K. Hale, Robert J. Thomas, and Willard Kent.

A communication from the secretary of "Boston 1915" was read, and Mr. Frank McInnes was made a committee of the New England Water Works Association to represent that Association at the conference of the "1915" organization.

On motion of Mr. J. Waldo Smith, it was *voted:* That, provided suitable arrangements can be made, Gloucester, Mass., be selected as the place for holding the next annual convention.

On motion of Mr. Morris Knowles, it was *voted:* That the President be, and hereby is, authorized to appoint a committee to arrange for the annual convention of 1911, with full powers, fixing the convention as near as may be to the second Wednesday of September.

Mr. Richard K. Hale was made a committee on the June outing, with power to appoint two associates. Messrs. G. A. King and W. E. Maybury were subsequently appointed.

A communication was received from Mr. C. E. Chandler with reference to statistics of Rainfall and Run-off, and on motion of Mr. Hale it was *voted:* That the President be, and hereby is, authorized to appoint a suitable committee to investigate the yields of New England watersheds, and such other watersheds as the committee may deem desirable, during the present dry period.

The President subsequently appointed Messrs. F. P. Stearns, H. K. Barrows, C. E. Chandler, X. H. Goodnough, R. A. Hale, E. E. Lockridge, Leonard Metcalf, A. T. Safford, and J. L. Tighe.

Five applications for membership were received and recommended for admission, namely:

For membership: Mr. C. Nelson Harrub, superintendent filter plant, city of Springfield, Mass., Westfield, Mass.; G. H. Abbott, treasurer Southbridge Water Supply Company, Southbridge, Mass.; Clarence Goldsmith, hydraulic engineer, Commissioner on Fire Protection, National Board of Fire Underwriters, New York City; Joseph N. McKernan, member water board, Plainville, Conn.

For associate membership: George W. Priest, Mansfield, Mass.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., Wednesday, March 8, 1911, at 11.30 A.M.

Present: Michael F. Collins, William E. Maybury, John J. Kirkpatrick, Robert J. Thomas, Richard K. Hale, Lewis M. Bancroft, and Willard Kent.

Nine applications were received and recommended for admission, namely:

For membership: Edwin D. Pingree, engineer Manufacturers Mutual Fire Insurance Company, Providence, R. I.; E. P. Ston, president Water Board, Saginaw, Mich.; B. N. Simin, engineer, Moscow, Russia; J. W. Ledoux, hydraulic engineer, Philadelphia, Pa.; J. L. Van Ornum, professor civil engineering, Washington University, St. Louis, Mo.; H. B. Andrews, civil engineer, Boston, Mass.; Randolph Bainbridge, commissioner of public works, Quincy, Mass.; H. M. Urban, chief civil engineer, T. C. I. & R. R. Co., Birmingham, Ala.; Wm. L. Wilcox, assistant chief civil engineer, Tennessee Coal, Iron and Railway Company, Central Water Works, Birmingham, Ala.

Mr. George W. Priest, president and manager of the New Hartford Water Company, was transferred from associate to active membership in the Association, by motion of Mr. Thomas.

On motion of Mr. Kirkpatrick, seconded by Mr. Bancroft, it was voted to hold a special meeting of the Association on the second Wednesday in April.

On motion of Mr. Bancroft, seconded by Mr. Hale, it was voted that the April special meeting be held in the city of Springfield, Mass., and that the President, Secretary, Mr. E. E. Lochridge, J. J. Kirkpatrick, and A. E. Martin, be a committee of arrangements, and that the subject for discussion be "Fire Protection."

Adjourned.

WILLARD KENT, *Secretary.*

OBITUARIES.

Louis E. Hawes died from apoplexy, at Wakefield, on January 29, 1911. Mr. Hawes was born in Springfield, Mass., on January 27, 1860. On graduating from the Worcester Polytechnic Institute in 1882, he became assistant superintendent of the Water Works at Northboro. In 1883, he was made assistant engineer on the construction of the Wakefield Water Works, and in 1892, he designed the sewerage system for that town, and became chairman of the sewerage commission in 1895.

Mr. Hawes has been prominent in the construction of water works throughout New England for the past thirty years. Among the works built under his direction are those at North Attleboro, Norwood, Ayer, Edgartown, Provincetown, Marion, Needham, Avon, Mass., Rockland, Me., Dover, N. H., and many others.

Mr. Hawes was married in Wakefield in 1886 to Hattie M. Emerson, who, with a son and daughter, survives him.

Mr. Hawes was a member of the American Society of Civil Engineers and of the Boston Society of Civil Engineers. He was elected a member of the New England Water Works Association on December 12, 1888.

Leonard Parker Kinnicutt* was born in Worcester, Mass., May 22, 1854, the son of Francis H. and Elizabeth Waldo (Parker) Kinnicutt. After graduation from the Massachusetts Institute of Technology in 1875, as bachelor of science in the department of chemistry, he spent four years at the universities of Bonn and Heidelberg, studying under the famous chemists, Bunsen and Kekule, and coming into contact with Hempel

* Memoir prepared by Leonard Metcalf.

of Dresden, Treadwell of Zurich, Anschutz of Bonn, and other well-known scientists, with whom he kept up a lifelong correspondence. Returning to the United States he studied for a year at Johns Hopkins University, under Remsen, and was then called to Harvard College as instructor in chemistry. For three years he taught there, incidentally taking the degree of doctor of science himself, and was then called to Worcester. There he spent the rest of his professional life, first as instructor, 1882, then as assistant professor, 1883, and thereafter as full professor,— being made director of the laboratory in 1892. He died of tuberculosis, February 6, 1911.

During the last twenty years or more of his life Dr. Kinnicutt devoted much time to problems in sanitary science, upon which subject he became a recognized authority. Frequent trips to England and the Continent, coupled with his keen interest in science and his winsome personality, kept him thoroughly in touch with modern tendencies and developments, and enabled him to perform a unique service alike to science, to the public, and to his fellowmen.

An indomitable worker, he found time to take an active part in matters of civic importance within his field, such as the experimental work in sewage disposal carried on by the city of Worcester, problems touching the city's water and milk supplies, courses of lectures for foremen and skilled mechanics, and many other questions of lesser importance.

The files of many professional journals and papers and the many quotations from his utterances bear witness to the activity of his mind and pen, while the attention and interest with which men listened to him bore witness to the soundness of his views. His last work upon "Sewage Disposal," written in collaboration with Winslow and Pratt, is the latest and best book of its kind upon this subject.

He was a Fellow of the American Association for the Advancement of Science, and member of many societies and clubs, — the American Chemical Society, New England Water Works Association (of which he was elected a member on February 8, 1893), Boston Society of Civil Engineers, Society of Bacteriology, the London and German Chemical societies, Association

of Managers of Sewage Disposal Works of England, and of the Worcester, St. Botolph, Bohemian, Harvard, and Tatnuck Country clubs.

In his college work Dr. Kinnicutt was most successful. His knowledge of his subject and enthusiasm as a teacher commanded the respect and attention of his students, but it was his knowledge of men, his real and helpful interest in his "boys," both as undergraduates and later as workers and men of the world, that won their loyal support and warm affection. It was to him, of all the faculty, that they turned, whether in need or trouble, or bubbling over with enthusiasm of new discovery or success.

Devoted to his family and his friends, his books and his garden, he was at his best in his home. Keen in his interests and judgment of men, catholic in spirit and taste, he was a rare host, and an addition to any group of men. A fearless yet courteous critic; of good poise and mental balance; a man of the world, yet always human; a lover of mankind,— he was worthy of the love men bore him.

New England Water Works Association.

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SOME DIFFICULTIES IN THE PURIFICATION OF WATER SUPPLIES.

BY DR. GARDNER T. SWARTS, SECRETARY OF STATE BOARD OF HEALTH OF RHODE ISLAND.

[*Read December 14, 1910.*]

I trust that the statements I may make will be considered merely as the result of experience in coming in contact with this question of purification of water in various capacities, — for instance, as secretary of a board of health, as the chairman of a committee on filtration of the common council for three long-drawn-out years, as a bacteriologist, and from constant contact with the strong and influential opinions of the best bacteriologists in Massachusetts and throughout the United States. The result of those experiences has been to convince me that a person who undertakes to secure the purification of a water supply is very much like the paternal member of the family who is sent to Boston to procure a Christmas present for the little daughter to present to the little boy. He finds himself on Tremont Street before the dazzling array of mechanical toys, and he wanders up and down trying to determine which will be the most satisfactory, which the most durable, which possesses the best mechanical qualities, and which he will best be able to operate when he takes it home. And then he reflects on the fact that Sarah has given him a whole nickel with which to make the purchase. That is the first difficulty most persons meet who undertake the purification of a water supply, — and I have passed through all the agony.

Assuming to be skillful engineers and practical men experienced in water matters, and looked up to by our learned legislators as men who will give them the best advice and the best and most economical methods, we find ourselves in an awkward position. We look over the field and we find that there are certain devices which are provided to take care of the particular water with which we have to deal.

You are all aware of the fact that water is water; but it is a little different water in one place than it is in another. Those of you who have traveled through New England and seen the limpid streams passing over the waterfalls into the ponds where the fish sport themselves in the clear water, cannot realize the difficulties and obstacles which are met when one comes to deal with waters in the western and central sections of the country, which are creamy to the extent of depositing perhaps a third of a glassful of sediment in the glass upon the table.

I can recall going to Chicago in my early days and seeing that condition, and all of you know the condition of the Mississippi and Missouri rivers. So, when you come to consider the question of the purification of water, you have many little problems to contend with at the start.

The difficulties which one encounters in this particular way may come after a perfect decision on the part of the engineer, or possibly of the person who has secured the contract for the filtration plant. A contractor takes up the question with the town council, and the thing is about as good as concluded that with his system he can take care of the water. But immediately objection is raised by some learned physician, who comes forward and exclaims, "Oh, but you are going to put chemicals into the water. I understand that mechanical filtration is not simply agitation of the water, or agitation of the sand through which the water passes, but you are going to put alum in the water, and don't you know what is going to happen then? Every citizen in the town will be ossified within three months! Every child that is coming to birth will come before its time!" Well, the horror of that in large headlines in a good solid newspaper makes a stir, and immediately the contractor is put in the background. These are personal experiences, gentlemen.

Then comes to the front those who have had long and varied and satisfactory experiences with perfect experimentation in the lines of sand filtration, which seems so simple in its processes, so easy to lay out and to operate, and their engineer has his hearing, and the good old doctor rises again and endorses this system with great gusto, proclaiming that this is Nature's method, that that is what we like to see, — the water carried through the earth and brought out pure and clear after being treated by these natural processes; not reflecting that the purest water he can think of is the old spring water on the farm, which he knows bubbles up from a depth of 100 or 200 ft. below the surface, and which he must recognize, as a man versed in chemistry, — or at least who should have been when he got through his primary course, — in coming from that depth has come in contact not with alum alone but with many other chemicals, and contains many elements which if analyzed out and given a name would make as startling headlines in the daily paper as the terrifying alum.

But that is something which is way back, and especially in our New England states, where we are somewhat conservative,— that is a very good recommendation to the people. They want what is old fashioned, they want what their grandfathers had, — the same old wells which have been used from generation to generation, accumulating in all the years the goodness of the families which have gone before. Likewise they know that the streams which are coming down from the mountains and the hills are also increased in their value by the manufactories which have been placed upon their banks, the waste from which is allowed to enter the stream. It is the same old stream, and they think it is the same kind of water and that it can be used with safety.

It is a hard matter to argue sense into some people sometimes, especially if they are of the old New England stock. We are of New England stock down in Rhode Island and we still have a good deal of that spirit which was brought down by the Dissenter, who couldn't get along very well with Massachusetts people and who so saturated the soil of our little state with independence that each individual citizen, no matter if he is an Italian of two weeks' life there, is an independent law unto himself, — and you can imagine what the old veterans are. Think, therefore, of the

difficulties we have when we ask them to adopt some system for purifying water, and then think of the difficulties we have to surmount when we are confronted with these various devices by which we are going to purify it. Suppose, for instance, we decide that we will take up sand filtration. We call upon the best outside engineers to tell us how it shall be done, and they approve a certain device. The local engineer understands his business; the outside engineer who is called in is going to earn his money, and he does, and he will recommend sand filtration as the best, perhaps as the best under the circumstances, inasmuch as the prevailing opinion in the council seems to deflect that way.

Then there is one particular thing which is raised as an obstruction, and that is that sand beds are objectionable because they may freeze up. But it is said in reply that that is not a thing to be thought of in New England. Water a foot deep anywhere, perhaps, beyond the line of Pennsylvania will freeze, but here in New England, where a sand filter is to be put in, it isn't necessary to cover that filter and add to the expense. The experience we had down in the little city of Providence was that while we started with the idea of paying $200 000 for a filtration plant, a filtration plant of sand which was to be uncovered, it has now been discovered as one which would freeze even in New England and needed covering, and it is now beautifully covered, sanded, loamed, and grassed, and it has cost us only $600 000. That is one experience. It is sometimes worth while to pay your money for what you learn. Of course at first it was simply the engineers, but the contractor has come across other difficulties. He meets with commissioners — I won't say what kind of commissioners, nor that it has been my experience, but there are certain commissioners whose thought is diverted at times by influences which may never appear upon the surface. I haven't had that experience; but evidently somebody else may have had.

However that may be, having overcome the difficulties of the commissioners and of the committees of the citizens, there is the engineer, who is always alert that everything shall be put in correctly, but he has certain devices of his own that he thinks ought to be introduced, and they are introduced through his influence, possibly to the detriment of the plant which was prop-

erly laid out by the original engineer, whether it be a sand or a mechanical filter. Then in some states you come up against the board of health. In Rhode Island the board of health is merely advisory; but in other states, — I think we are in one of those states now, — and states like Ohio and Indiana, and all out through the West, they are alive to the fact that there are some new ideas.

Then there is the experience, as it comes to daddy after he comes home with the nickel purchase and regrets, the moment he sees the children with the toy, that he did not chip in a quarter and get a better instrument. But with us the toy is the plant, and the plant is there, and we have got to do the best with it we can. And what is the best? My innocent experience in these things has shown me that no matter how good the plant is, and how well it is put in, it will not work of itself, as the toy did on Tremont Street. It has got to have a little supervision. You have got to pay a little money, not for the extremely expert knowledge, but you have got to pay a little money for horse-sense, and it is mighty hard work to find it, — just plain, common horse-sense, from the head of the department down to the man who shovels the coal.

Now, the operation of a plant looks simple. It is nice to build cement masonry now, for we can make pretty structures, and can use most any shape or form and get any strength we need, we can put in centrifugal pumps and pipes and what-not indefinitely, and all manner of devices which on paper in the engineer's office look fine and when they are erected start out nicely. But, like the toy in the Christmas carol, the thing comes to a stop, or, rather, some of the wheels don't go around. I am not speaking of any particular plant, you understand; I am simply speaking of experience with plants in general. The same may be true of other forms of filters beside mechanical filters.

When those wheels come to a stop, some one has got to find out why they have stopped. And it has been, I think, the practice of most of those companies who have their business interests at stake to look after these plants and leave directions at least in typewritten form how, even with a little mechanical experience, the plant may be run, chemically and bacteriologically. It seems to me to be obvious that any one who wishes to continue in the

business of putting in these plants must follow up the experiences which result from their use. And those experiences have been in many cases most interesting. Where a device will accomplish one thing in one locality, the same device in another locality will not accomplish the same thing. Perhaps the same water is used, perhaps the same instructions are given; but those of you who have had experience in water matters know that with a freshet, or with a hard rain, in the average stream what is the water of to-day is not the water of to-morrow. What takes a certain amount of chemical to accomplish certain results in purifying the water, so that the proper effect will be produced and proper filtration follow, may not be the same to-morrow. So it may be given out to those who are to run the plant that they have a water of such a quality, and that they should use a certain quantity of coagulant, which in this case we will call alum, and things should run as they ought to. But a little while after, being on a stream which is perhaps influenced by mechanical industries, the water begins to get too acid. There may be jewelry establishments, there may be iron works, on the stream. No one at the works knows that the water has changed in its acidity, but it is discovered that the color, which previously was below 10 on the graded scale, has run up to 40 or 50 without any particular reason. It is discovered, too, that the bacteria which have come from the filter in the filtered water ranging 50 as against 3 000 in the stream are now running into the hundreds in the filtered water. It is a puzzle to those who are managing the plant, and the question then arises what is to be done? Simply a little horse-sense given out in the beginning, and absorbed by the individual who is running the plant, corrects these matters.

It is necessary, therefore, that there should be some control of plants by an authority which is subservient to the public, a commission of water control, or, as is our experience in most states, the board of health, who take and have, as in Massachusetts, the control of the water supplies which are to be delivered to the constituents of the board of health. Unfortunately in our state we have no such control. It must be remembered that many of these plants are placed in operation under the pernicious influence of an individual owner, a private supply, over which the

public has not control; or it may be that a city council's treasury runs a little low, and there is a cut on the alum; and there comes another question, — as to the quality of the alum. Certain alum was given in the beginning and it worked nicely; certain sand was given and that worked nicely; but for economy's sake there is a curtailment in the price of alum. Along comes an alum producer, and he offers a barrel of alum at very much less price than a previous purveyor of that article, and we don't get the same results; we are not getting the same amount of alum.

Furthermore, it may be that after the alum has worked nicely it is found that the water has become too acid and it is necessary to add a certain amount of alkalinity. Now, to the difference in the quality of the alum may be due the difference in the amount of alkalinity which is added, in order that the alum may bite and have its agglutinating effect upon the organic matter. Otherwise the *Schmutzdecke,* the covering upon the filter sand, does not form, and the result is that water comes from the filter which is not suitable to drink, nor for mechanical, bleaching purposes, or steam production, all through a little slip, perhaps; and that slip, my experience has shown, has come either through good-will, political or other pernicious influence — but most generally good-will— whereby old John, who was the engineer for the last quarter of a century, has pumped the water and kept the machinery well òiled, is put in charge of the mechanical plant and told to run it. Things may run wrong for awhile, but no one has the courage to dismiss him. At last a pension may be found for him and a new engineer may be put in who has a little life and has a little common-sense; instructions are given him which are followed up and controlled by the chemist or bacteriologist, whoever is in authority, and by those who are above the chemist or bacteriologist who has control, as indicated in regard to water commission controls. Under these conditions proper results can be obtained, and a clear, pure water can be furnished to the people.

All these difficulties and troubles, or others like them, and the sad experience which comes with them, — and which comes in nearly every plant because the water varies and the influences which control the plant vary, — may come to you in the varying conditions of sand filtration. Perhaps I ought not to speak about

sand filters here, where I am on their native heath, so to speak. Perhaps I ought not to say a word with regard to them, but I am simply telling now of my experiences. With sand filtration you have, perhaps, an ideal condition, if the conditions are favorable, — a water which has not too much sediment in it, plenty of good sand in the immediate vicinity or within a short haul, plenty of area which is not expensive, an experienced man to control the plant, and good workmen to work under him. But, unfortunately, here politics come in. There must be fifty men hired where twenty would do the work, and that fifty are usually of the quality, or may be of the quality, which is not desirable even for shoveling sand. And yet it is expected that with these men the sand, which must be removed from the surface of the beds, will be removed nicely and carefully in order that the surface of the beds may not be broken up and disturbed. It can be done, but it requires supervision and it requires experience on the part of those who have control of the plant. When I look upon a sand filter plant in New England, and compare it with one of the mechanical filters, it makes me think seriously of ancient Egypt, where the water was raised from the river bucket by bucket, and the manual labor which was required to introduce the water into a town or city was out of all proportion. If mechanical devices were introduced, as they are in mechanical filtration, with the same difficulties and the same chances, it would seem a little more Americanized and a little less heathen. But the heathen are waking up, I understand, for mechanical filtration plants are now being placed in India, Egypt, and Japan.

Now, after one has gone through all this enjoyment and pleasure of seeing the operation of his toy, lots of little difficulties come up. There is a question which arises as to the method of cleaning the bed, whether to devote three or four whole days or a week to cleaning a sand bed, and then take a week or so for washing the sand before it is returned to the bed, and then have all the labor to perform of carrying the sand back to the bed. Then there is the difficulty of understanding why at certain times when our mechanical bed is working smoothly and nicely, suddenly there is a "fluffing" of the sand and an inoculation of the whole bed which no one can understand. Those are matters which come up

and are extremely interesting, and as they come to us at times we take them with the feeling that we are glad to see something different in order to have the pleasure of studying it out. There is the possibility that your alum feed is put in at the wrong place, so that there is not sufficient time for coagulation of the alum, and the organic matter in the water is not long enough in contact with the alum.

But, after all is done and told, we get our beautiful white water in our sump basin, we have alumed it, we have hypochlorited it, and we pass it into our reservoirs in that state, and suddenly there are telephone calls from all parts of the city to the health department, " What is the matter with the filtered water? What kind of chemicals have been put into it? It smells as if all the dead clams on the shore had got into your reservoir." Of course we know what to do, but we are modest, we are very innocent, and we simply say, " Those are the beautiful organisms we call algæ. If you could only see the beauties of these algæ under the microscope you wouldn't smell a thing in the water." But the people have no microscopes, and they don't care for microscopes; they simply know that the water stinks, and if something isn't done about it they think the whole population will die, and there is trouble for the health department, and we have to quiet their feelings. They say, " How long is this going to continue? " We reply, " Well, these organisms usually live about two months, sometimes three, when they die out, and then the thing will stop. And it will stop all of a sudden, too; you will be surprised and interested." Well, they haven't any interest in what is going to happen in three months; they are interested in what is happening just now. So our friend comes to the front with his chemical knowledge, and he takes a bag of sulphate of copper and goes up and down the reservoir — and he does it early in the morning when nobody else is looking on, for fear the reporters will get hold of it and say that there is more doping of the water going on; and he succeeds in bringing about a beautiful result. In a couple of days the algæ have disappeared, and the odor has disappeared, except what may be left in the pipes. But in a few days there is more trouble. An examination of the water shows that while we have killed off the asterionella, or some other organ-

ism, another little "bug" has come to the front which can live where the other one can't; but we haven't quite so much to apologize for because there is now a geranium or lemon odor, yet that is sufficient so that the users of the water are disgusted with the plant.

We have no control of that at the present time. It is impracticable to cover over the reservoirs so that this clear water, in which the organisms grow with so much facility, can be protected from the rays of the sun. Therefore, we have got to find out — and that is something which all of us ought to put a hand to — how to prevent the algæ getting in to start with, how to prevent the little seeds from going from place to place, and if it is possible to kill them out in one place so that they will not be blown to another. Here arises a line of study which will be held open to those of the coming generation. We had hoped it might be finished here with us, but unfortunately it apparently will not be.

There is one thing with regard to mechanical filtration which interests me, and it is not clear to my mind, although those who have charge of the introduction of these plants can explain it to you very lucidly, and that is the difference between the air-wash, and water wash with the mechanical agitation of the rake. I have seen both plants in operation and have watched the rakes go "round," and personally I can see very little difference. For instance, I assume that the air-wash is the forcing of air underneath the bed, which has settled down or choked after the filtration has been completed, so as to break up this *Schmutzdecke* or covering of coagulated sediment which has formed on the top. The wash water from below carries off this surface of decayed material, the bed is then allowed to settle down to its normal state, the sand having been cleaned, and the operation again goes on. In the mechanical or rake pattern, the tanks instead of being oblong are circular and revolving rakes cause an attrition or contact of the bars against the sand, and grains of sand against each other, theoretically scouring the sand more thoroughly than the air-wash.

But with all the air-wash there comes at times a condition of the "fluffing" of the bed. The bed seems to be spongy, and for no particular reason. The grains of sand do not seem to be covered with any particular slime, but there seems to be softness

to the bed which does not allow perfect filtration. Then we begin to say that the air-wash is at fault, until we find that in the same kind of a plant the beds with the rakes begin to fluff also. I shall not attempt to tell you why this is, because I do not know. There may be others here who are experts in the work who can tell you, and they will tell you, perhaps, for a consideration, or out of the kindness of their hearts. At any rate, it is a thing to be found out, and is extremely interesting.

Now, gentlemen, these are some of the experiences which have happened to me as an individual, and as an official of a board of health. Possibly some of you may have had such experiences, and many of you will have them in the future; but pray, when you go to buy your plant, whether it be sand or mechanical, stop and think whether it is a smooth waxed floor that the toy is going to be run on, or whether there is going to be a carpet there; stop and think whether it isn't policy to take twenty-five cents out of your pocket and spend it rather than to get a cheap toy. Go to those who understand these things, to the engineers who have had experience. They have different opinions among them, but they all have one common source and fount of knowledge, and they have the same opinion, really, although they may express it a little differently. They can tell you, and you ought not to try to use your correspondence course in this line, for it will be expensive. Go to those who understand the work and have been through all these troubles. I am not speaking of those who sell the plants, or those alone who have the knowledge to tell you how to select a particular plant or how to care for a particular water, but go and learn from the experience which comes to you from such sources as the State Board of Health of Massachusetts, which has devoted years and years to a study of the questions of filtration, and whose tomes and volumes, which seem to you to be endless in the way of figures and lines and columes, have been the source of valuable knowledge which has been acted upon throughout the whole world, for the benefit of civilization and for the benefit of all those who have taken up this question.

Now, gentlemen, you are all water-works men. You know how the pumps work, you know how the filters ought to work, you

may have had some of these experiences or you may have had others. But all I can ask is that you will take the statements which I have given to you to-day and think them over before you attempt to indulge in the luxury of a five-cent toy. Then I think, perhaps, our time will have been fairly well spent.

DISCUSSION.

Mr. Gilbert H. Pratt.* Dr. Swarts's experiences and mine have been linked together for the last five years, and in that time I think I have met nearly all the difficulties that he has spoken of. The thing resolves itself, in a few words, to the concluding remarks that the doctor made, and I would express it in this way: When you want advice, go to a good doctor; and when you think that you may have some trouble the matter with you, don't try to fix yourself up.

I wish to emphasize the point that the doctor made, that waters vary greatly even in the same locality, and the same waters will vary to a decided extent from month to month, and at times from day to day. I have had experiences in connection with municipal water works and in consultation work I have had to do with mill plants, where I have had that fact brought very forcibly to my notice, — where waters which might be of a certain character at one time, to use a crude expression, " went all to pieces," and could not be handled by the previous process, — not that the essential process was at fault, but in some little point some little change had taken place.

The variation in the flow of the stream as to its alkaline contents is a very serious proposition which keeps coming up all the time. In one case which I have in mind, a mill plant had operated beautifully for years, and then things went all to pieces so far as the output was concerned. All that was needed in that case was the introduction of a very small dose of carbonate of soda, and the plant was on its feet again, turning out the same bright water.

Mr. Harry W. Clark. † I have no prejudice against mechanical filters in their right place and if they will do the work

* Chemist, Rhode Island State Board of Health.
† Chemist, Massachusetts State Board of Health.

that other filters will. You must remember, however, that the primary object of a health board when advising in regard to water filtration is generally to be sure that the health of the people is to be benefited by such filtration. Of course there are times when the only object is the improvement of the physical character of a water. Obtaining a nice-looking effluent is not often the first thing to think of, however, important as that is. The first thing to be considered is, generally, will filtered water improve the health of the people using it?

I would like to call your attention for a few minutes to an article written recently by Dr. Sedgwick, of the Institute of Technology, and Mr. McNutt, a health officer in a New Jersey town. This article was published in a late number * of the *Journal of Infectious Diseases*, and is a description, with illustrations, of what the authors call the Mills-Reinke-Hazen theory, which is that, wherever slow-sand filtration plants are introduced, not only are the deaths from typhoid reduced, but the total number of deaths from other diseases also. Mr. Mills, the engineer member of the Massachusetts State Board of Health, discovered this to be true when studying the death records of Lawrence after the introduction of sand-filtered water. Compared with a number of years before the introduction of this water, the deaths of the city decreased after the construction of the filter 15 or 18 per cent.; that is, the death rate went down from something like 23 to 16 or 17 per 1 000; I do not remember the exact figures. Now, in this article by Sedgwick and McNutt, the results upon the health of the people of the construction and operation of what they call eight sand-filter plants, are given, the results being, of course, shown by deaths from typhoid fever and total deaths from all causes. In the article they speak of the great reduction at Hamburg, Lawrence, Albany, etc., where sand-filter plants are in operation, — and they include Watertown and Binghamton, N. Y., in the list of sand filters also. As a matter of fact, however, Watertown and Binghamtom have mechanical filter plants. Sedgwick and McNutt do not seem to realize this, and call attention to the fact that these two plants, namely, those at Watertown and Binghamton, do not follow the general rule of sand filters in the reduction of the

* Vol. 7, p. 489.

death rate of the community they serve. If you will study broadly the reduction of death rates at various places after the introduction of sand filters or mechanical filters, you will see clearly, I believe, that almost invariably when a good sand filter is put in, not only are typhoid and typhoid death rates very materially reduced, but the total death rate also, and that following the introduction of mechanical filter plants of the best design, the death rate in communities served by them is not reduced as distinctly as by slow-sand filters. I do not say that there may not be some other cause than the different methods of filtration, and that there are not exceptions to the general rule, but the statement made is true. So I wish to repeat that the first province of a health board is to advise in regard to the health of the people, and in the subject under discussion the probable effect upon their health of a proposed filter plant. When mechanical filters can show as good results as sand filters in this respect, there will be more to be said in their favor. Of course I know about a lot of these mechanical filter difficulties in Rhode Island and elsewhere, and I do not mean to say that there are not difficulties often in the operation of sand filters. I know also, as Dr. Swarts has said, that mechanical filters are in operation in India, Japan, Egypt, and other foreign countries. I think, perhaps, they ought to be operated there first, for the old reason of "trying it on the dog." Personally, I like to see the water that comes from a good mechanical filter plant. It is generally clear, colorless, and attractive. There is no doubt that many people like it and I do not doubt that mechanical filters of modern construction when well operated with the waters to which they are best adapted, produce a satisfactory effluent at many places. With the clear, soft waters of Massachusetts, however, free or nearly free from turbidity, mechanical filters appear to be unnecessary, and we must not forget the first reason for filtration of polluted water, — improvement of the health of the community.

Mr. Robert S. Weston.* When we consider the difference between the point of view of those who favor mechanical filters and that of those who favor sand filters, we ought also to realize

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*Sanitary expert, Boston, Mass.

how much nearer these points are to each other to-day than they were a few years ago. We can remember, for instance, when a sand filter which operated at a rate of 2.6 million gallons per acre per day was considered to be the standard, and when the mechanical filter companies were advertising and selling filters based on a rate of something like 250 to 300 million gallons per acre per day. Then we had a series of studies by the Massachusetts State Board of Health, by Mr. Fuller and others, which has resulted, I think, in reducing the rate of mechanical filters to something like 125 million gallons per acre per day; and increasing the rate for sand filters to from 6 to 10 millions gallons per acre per day. Thus the rates of filtration are approaching one another. It operates, of course, to reduce the difference in construction cost between these two filters.

Then, again, there has been a great improvement in the method of cleaning and operating sand filters. It is a great disadvantage in the operation of sand filters under existing conditions that such a large crew is necessary to scrape the sand beds. This is especially disadvantageous when the sand has to be cleaned frequently, which is the case with a water which is between the clear type of water, to which sand filters are especially applicable, and the turbid type, which is, perhaps, most readily purified by mechanical filtration. In such cases, where scraping must occur frequently, the labor cost is very high, thus assisting a movement which, I think, is towards the mechanical type of filter. The first step in that development was taken, I think, at Lawrence, where the scraped off sand, instead of being transported in wheelbarrows to the sand washing floor, was removed by ejectors. Subsequently, at Washington, the sand was removed by ejectors, washed, stored in bins and then carried back by carts and men. More recently ejectors have supplanted the carts, and finally a machine has been devised for cleaning the sand in place, by which the sand is taken off of one filter by a scraping machine and passed through an ejector and washer into an unused filter.

Another step in this direction is the Blaisdell system, where the sand is washed in place by what is practically a traveling hydraulic rake. It traverses the surface of the sand, and by means of hydraulic jets reaching down into the sand transforms

successive portions of the area into mechanical filters for the time being, as far as the cleansing process is concerned.

Then another way in which I think the sand filter is imitating the mechanical filter is in the arrangement of the pipes and rate-regulating devices. The New Haven filters were the first step in this direction. The sand filters instead of being placed along both sides of a court were arranged on two sides of a gallery, like mechanical filters, with the piping all exposed. In this way I think the sand filter has been improved by the presence of the mechanical filter, just as the old system of dosing with mercury and drugs was improved by the promulgation of the homœopathic theories of medical treatment. Likewise both slow sand and mechanical filters may be succeeded by systems possessing the excellencies of both, for the more one studies the facts the more one realizes, first, that there is no one type of filter suited to all types of water; and, second, the two types of filters which we call slow sand and mechanical are a great deal nearer together in their design than they were fifteen years ago.

Another point, mentioned several times before, may be emphasized. It is the value of appearance. When one advocates a water supply, especially a purified water supply, one must promise water which is agreeable, or people will not drink it. If they will not drink the water they will go to springs for their drinking supply, and these may have any sort of sanitary character whatever. For that reason it is as much a matter of sanitary importance to furnish water of good appearance, such as a mechanical filter can produce with a highly colored water, or a sand filter with a fairly clear water, as to reduce the number of bacteria contained in the water.

We very soon will have an example of the two types of filters operating with one water at Montreal, where, I understand, mechanical filters will be used for a part of the supply, while the rest of the city will probably be supplied through sand filters, operating at a 10 000 000-gallon rate.

Dr. Swarts. I have nothing particular to say in closing the discussion, except to state that I am very much pleased to hear Dr. Clark state that there may be other influences than filtration which will cause a decrease of mortality sometimes.

If we depended upon statistics entirely, for information with regard to the advantages of a filter, we should hardly want to hark back to conditions at Washington, where an ideal sand-filter plant has been installed and pure water secured, and immediately the typhoid death rate rises. Not one of us would assume that the plant was at fault, that it wasn't a perfect filter, and yet the typhoid fever rate goes up. There are other influences, and those influences are not all discoverable, for by a thorough examination made of 5 000 cases of typhoid within a certain time in the District of Columbia, through the Marine Hospital Service and that of the local district authorities, it was found that one could ascertain the cause of typhoid fever in only about 65 per cent. of the cases; and of that number those who partook of filtered water made up only about 15 to 20 per cent. Where the largest amount occurred was where water was used which was taken from other sources. So I think statistics are a little deceiving, and ought not to be quoted against any sand or mechanical filter plant.

Mr. Clark. I agree entirely with what Dr. Swarts says so far as it goes. We can pick out special instances in almost any matter to illustrate the other side, but I am talking about average results from average good sand filters and average good mechanical filters.

Mr. Robert E. Milligan.* Mr. President, it has been a real pleasure to me to hear the apologies for slow-sand filtration. In the last twenty-five years I have had occasion to examine and to hear results from both sides. While it is unfortunate, in one sense, that I might be considered as predisposed toward mechanical filtration unduly, I hope the Association will quite believe me when I say that my sympathies are with the branch of water purification that I have been identified with so many years. Mr. Clark has, of course, made certain statements which I think any one can recognize as opposed to mechanical filtration, and identifies two particular plants as being notable failures in that respect. Speaking from memory in answer to this (while I am sure he is sincere in desiring information), I think the case of Elmira is an exceedingly poor citation in this connection. Possibly no city in the United States has been so carefully combed for

* Manager New York Continental Jewell Filtration Company.

sanitary results as that same city of Elmira, and, so far as I could ever see, chiefly because they were unfortunate enough, some fifteen or sixteen years ago, to put in a mechanical filter plant in opposition to the slow-sand method. In the Washington investigation, Elmira was used as a horrible example — and perhaps the most horrible example at that time — that was forthcoming against mechanical filtration. Notwithstanding the fact that mechanical filters had been introduced there and had been in operation, I believe, about two years, there wasn't any noticeable decrease in deaths from typhoid fever. The explanations of the superintendent and the local board of health as to this were apparently not satisfactory to the commission who were interested in recommending slow-sand filters for the city of Washington. These gentlemen of Elmira having some idea that, being United States citizens with very strong backbones, it was possibly up to them to put in shape the reason why the city of Elmira had failed to disclose the reduction in typhoid fever that anybody with a sane and normal mind would expect would follow the introduction of mechanical filtration, the situation was investigated, and it can easily be proved to Mr. Clark, or to the Massachusetts State Board of Health, that the cases in Elmira which showed the high death rate from typhoid fever were almost wholly due to wells and other causes among the water-takers who did not use the supply that the water company of the city of Elmira furnished from mechanical filters.

The city of Elmira was supplied by water from a water company, which, of course, is against them on the face of it. These gentlemen naturally could not supply any more takers than were quite willing to take the water from the water company. No coercion, of course, was possible, and each man who had a well in his back yard, and each milkman who washed his cans from a well in his back yard, had a grievance, and a *prima-facie* case, in opposition to the water company who were furnishing a bright, clear, and, as the water company contended and the analysis showed, sanitarily pure water. I do not believe any one who will take the results from the city of Elmira the last ten years, take the analyses — and they have been compiled without any leaning or bias towards the process of mechanical filtration — could doubt for a single

minute that they have enjoyed one of the most potable and pure supplies in the United States. These are statistics, and it certainly is a great pleasure to me to call Mr. Clark's attention to them and I would be very glad indeed to furnish the data at any time proving these simple facts.

There was another point raised by Dr. Swarts that I should like to speak of, getting back to mechanical filtration, and that is, the devices that are peculiar to it. I want to say right here that it isn't very difficult to differentiate between the two processes of filtration, notwithstanding Mr. Weston's very clever assimilation of these radically different processes. The fact remains that mechanical filtration depends very largely on the use of a coagulant, of a chemical, — any word, no matter how harsh, — to coagulate the water before it goes to the sand beds. In the system which Mr. Weston has called to your attention, they have raised the rate to 10 000 000 gal. per acre as against 2.6; but you must not lose sight of the fact that Wilmington in raising the rate of slow-sand beds has not forgotten to first purify the water through a mechanical filter, using a coagulant. I am not calling attention to this in any sense of criticism. Notwithstanding the fact that the process known as slow-sand filtration came from Europe, does it really follow that the American idea of coagulating water,— and it is purely an American idea so far as mechanical filtration as a means of purifying water supplies is concerned, — because it is an American idea, should receive the opprobrium and the censure not only of the great body of engineers but of the state board of health as well? It may be that the two things are coming closer together; but, if they are, it must be evident to any one who has ever been associated with the purification of water that mechanical filtration is not stepping in that direction as fast, nearly as fast, as slow-sand filtration is coming towards the process that you all know as mechanical filtration.

In regard to the air-wash and the agitator, there is a great division of opinion to-day, and there probably always will be, as to whether a mechanical filter can be washed as well by air as it can by an agitator. I suppose, if I belong to any school, I might be termed an air-washing filtration man; and yet I am not satisfied in my own mind that we have got very much beyond

the value of a rake or an agitator in washing sand. I suppose, and I guess Mr. Weston will bear me out, that there has only been one real test that would satisfy everybody made in this country as to the comparative value of an air-washing filter and an agitator filter under exact conditions with the same capacities; if I am not mistaken, that was under the direct observation of Mr. Weston himself at New Orleans. And if my recollection serves me further, the result there was that the effect of washing a sand bed with air as opposed to washing with the agitator was sufficiently similar that, all other conditions being the same, there wasn't any reason why one or the other process should not be used. That is as near as my memory of the particular case goes, and I think Mr. Weston will bear me out.

So far as the case both Dr. Swarts and Mr. Gilbert Pratt referred to, of the fluffing of the sand bed, which occurred at Bristol-Warren, R. I., my own estimate of that condition was that it was due not in any sense to the method of washing. The Bristol-Warren supply is probably as difficult a supply to handle as exists within my knowledge of purification to-day. The color has gone as high as 180, which is about the color of strong coffee. In addition to that, if there is any form of algæ which does not exist there, it is simply because no one has ever taken the trouble to catalogue it; it was there, I am satisfied. Now, we all know that in the last two or three years most of the ponds and impounded reservoirs in the country, and the sections of the country which depend on them, have been subjected to considerable drought, and all the conditions which turn the hair of the filtration man white have been present to a tremendous extent — and Bristol-Warren wasn't any exception to that condition.

My idea is that the algæ condition at Bristol-Warren produced a raw water carrying to the filters a large quantity of soluble and suspended organic matter, mostly soluble, for there is very little suspended organic matter in the water, as I remember it, and this organic matter was drawn into the bed beyond what might be called the filtering zone, that is, the eight or ten inches from the surface, into the body of the bed, where it became a source of secondary pollution; and no matter what percentage of the amount may have been removed by the superimposed layer

of coagulum, the partially purified water coming into contact with this mass of rich organic soluble material again received its quota of food, and the bacteria increased to an extent which was almost inconceivable. There is nothing really new about it. The old Warren mechanical filter, for example, with its dark, clear water basin underneath, sometimes developed that trouble, and we could tap almost any part of the filter bed above the strainer system and get 90 to 99 per cent. reduction of bacteria; and yet in the under channels there was found increase at times due to inefficient methods of washing or perhaps construction. Now, whether or not in the case of Bristol-Warren an agitator as opposed to the air-wash would have removed the difficulty, there is no way of knowing. Apparently not. As I say, the only real knowledge we have as to the relative merit of the two methods is from those experiments at New Orleans where an air-washing filter and an agitator filter side by side operated under exactly the same conditions.

REPORT OF THE COMMITTEE APPOINTED TO INVESTIGATE THE CONDITIONS UNDER WHICH EXTENSIONS OF MAIN WATER PIPES ARE MADE.

[*Presented January 11, 1911.*]

To the New England Water Works Association, — Your committee appointed to investigate the conditions under which extensions of main water pipes are made in municipally owned water works, particularly with reference to the requirement of a guaranty, respectfully report as follows:

A blank form, copy of which is reproduced in Appendix A, was prepared and sent to all the municipally owned water works in New England as far as we had record of them; also to our members who have charge of similar works in other parts of the country. Through oversight, a number of these forms were also sent to members who are managing private water companies, and a few of these have replied with statistics which are outlined below, although these are without the field of the inquiry as planned.

One hundred and forty-one replies from municipal works were received. The principal data contained in these replies are presented in Table 1, below, which shows the municipalities which do and which do not require a guaranty, and the terms of such guaranties as far as they can be stated in a few words.

It should be noted that, practically without exception, these guaranties are required only when there is doubt about getting sufficient income, in the form of water rates, from an extension of the pipes.

Analyzing the returns in a rough way, it is seen that 73 places, or 52 per cent. of those reporting, require a guaranty, and 68 places, or 48 per cent., do not. In this classification, works reporting that guaranties are " usually " or " sometimes " required are included among those giving a positive answer, while those which " rarely " require guaranties are included in the negative column. In a general way, therefore, it may be said that about

one half of the municipal water works require guaranties before extending water pipes in regions where the returns are doubtful, and the other half do not.

An examination of the table indicates further that the practice of requiring guaranties is more common in small towns than in the larger cities, although this rule is by no means invariable, since Boston requires a guaranty in the form of a cash deposit, equal to 25 per cent. of the estimated cost of the pipe line (or, in other words, the equivalent of 5 per cent. income for five years).

With regard to the amount of the guaranty, the practice is not by any means uniform; indeed, the percentage of cost which is considered a fair return varies very widely, as shown by the following statement:

10	places	require	a	guaranty	of	4	per cent.
17	,,	,,	,,	,,	,,	5	,,
19	,,	,,	,,	,,	,,	6	,,
4	,,	,,	,,	,,	,,	7	,,
8*	,,	,,	,,	,,	,,	8	,,
13	,,	,,	,,	,,	,,	10	,,
1	,,	,,	,,	,,	,,	12½	,,

The average percentage for these 72 places being 7.6 per cent.

It is worthy of note that in the state of New York guaranties are not necessary as, in accordance with the state law, undeveloped property is assessed water rates upon a definite basis per foot of frontage, and these rates are collectable in the same way as taxes and are a lien upon the property. In this way lots which are not built upon assist in bearing the cost of water pipe extensions and in maintaining the works. In the case of Albany the amount so assessed on vacant lots is 10 cents per year per front foot. Lumber yards are similarly assessed 20 cents per front foot, and buildings to which water is not supplied are assessed upon a specified scale.

The *form of guaranty* required from parties interested in securing extensions of the pipes varies considerably. We give in Appendix B copies of the best forms of such guaranties which were submitted to us. With these as a guide, any superintendent should be able to prepare a suitable form which will fit his own conditions.

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* Including one place where the percentage varies from 6 to 10.

With regard to success in collecting guaranties, experience varies widely. Some places report very poor success, others no trouble whatever. It would seem to be the best practice to require a bond with suitable surety, as is the custom in a number of places. An examination of the forms of guaranty will indicate that some of these are in themselves bonds.

Another question which has not received by any means a uniform solution in different places is that of the permanency of the guaranty. Many places apparently put no time limit to the guaranty and presumably expect to collect it until the income, in the form of water rates, reaches or exceeds the amount guaranteed. Other cases require a stipulated percentage for a definite term of years, — for instance, 5 per cent. per annum for five years.

In nearly every case all sums received as water rates from takers upon the line of pipe are credited against the guaranty, but in a few cases the percentage guaranteed is required in addition to whatever water rates may be received.

In addition to the statistics of municipal works, replies from 13 water companies were received, containing more or less information. Eight of these 13 require a guaranty. In 6 cases the guaranty is 10 per cent., in one case 15 per cent., and in one case $7.00 per 100 feet of 6-inch pipe and $9.00 per 100 feet of 8-inch pipe.

The original answers which we have received have been bound in book form and deposited in the Association's library, where they are accessible for further reference at any time.

Respectfully submitted,

CHARLES W. SHERMAN,
EDWIN C. BROOKS,
A. W. F. BROWN,
GEORGE H. ROBERTSON,
NORMAN A. McMILLEN,
Committee.

APPENDIX A.

[Form of Circular.]

CONDITIONS OF MAKING EXTENSIONS OF MAIN WATER PIPES.

New England Water Works Association.

Boston, January 25, 1910.

The undersigned have been appointed as a committee to investigate and report upon conditions under which extensions of main pipes are made by municipally owned water works.

The following data are desired by the committee, and members of the Association and others who can contribute such information are requested to fill out the blanks and return this form as soon as possible to Charles W. Sherman, 14 Beacon Street, Boston, Mass.

Charles W. Sherman, *Chairman*,
Edwin C. Brooks,
A. W. F. Brown,
George H. Robertson,
Norman A. McMillen,

Committee.

1. *Place.*
2. *Control of Water Works vested in :*
   - (*a*) Water board of members.
   - (*b*) Single Water Commissioner.
   - (*c*) Committee of City Government.
   - (*d*) Other Officer or Board (state what).
3. *What authority decides when extensions of main pipes shall be made ?*
   - (*a*) Water board or commissioner.
   - (*b*) Town meeting or city council.
4. *Is a guaranty from prospective water takers required before an extension is ordered ?*
5. *Give particulars relating to guaranty when required.*
   - (*a*) Percentage of actual cost.
   - (*b*) Percentage of estimated cost.
   - (*c*) Percentage of estimated cost of a 6-inch pipe.
   - (*d*) Guaranteed revenue per 100 feet of extension.
   - (*e*) Other form of guaranty.
6. *In case a guaranty is required, is the amount in any way dependent upon or affected by the following factors:*
   - (*a*) Improvement in fire protection to be obtained by proposed extension.
   - (*b*) Improvement in circulation.
   - (*c*) Other factors.

7. *In computing actual or estimated cost of extension upon which percentage guaranty is based, what items are included?*
   (*a*) Cost of labor and materials only.
   (*b*) Cost of inspection.
   (*c*) Cost of holidays, vacations, or other absences with pay allowed to persons engaged upon this work.
   (*d*) A proportionate cost of office and other standby expenses.
8. *If a guaranty is required under a city or town by-law, quote by-law.*
9. *Quote form of guaranty required.*
10. *What has been your experience in collecting such guaranties?*

Dated 1910. Report by

APPENDIX B.

FORMS OF GUARANTY OF REVENUE REQUIRED BEFORE MAKING EXTENSIONS OF WATER PIPES.

1. Beverly, Mass.

Know all men by these presents, that we, the undersigned, owners of land, or land and houses, fronting and abutting upon Street in Beverly, in the Commonwealth of Massachusetts, do hereby severally agree and further bind ourselves, our heirs, executors, administrators and assigns,

In consideration of the laying of a water pipe or pipes, to wit, about feet in length, be the same more or less, in said Street, by the city of Beverly, a municipality duly incorporated by the Commonwealth of Massachusetts, by and through the Water Board of said city, for the use of said pipes, or for the consideration aforesaid, such sum or sums, payable by such annual installments, to be apportioned by said board, as shall equal in the aggregate the amount of at least four (4) per cent. of the entire cost to the city of said laying, said apportionment to be made according to

;

and said installments shall continue to be paid by us in the manner above mentioned, until said amount of four (4) per cent. shall have been fully paid, or until said board in its discretion shall become satisfied from whatever cause to establish an annual regular fixture-rate, in which event said four (4) per cent. basis shall be substituted by such fixture-rate, under the law and rules of said board duly made and provided.

2. Boston, Mass.

$. . . . .

Received of the sum of dollars, being the difference to make up per cent. for five years on the cost of laying water pipes in Street, as per petition on file dated ; said amount being received on deposit for five years unless sooner cancelled by income from water rates. Any additional income derived on the line of pipe laid under said petition within five years from date will be refunded at the expiration of that period, but should there be none, then the whole amount will be forfeited to the city.

Preserve this receipt.

3. Bridgeton, N. J.

To the City Council of the City of Bridgeton, — We, the undersigned, hereby make application for the laying of a main pipe in Street, of a suitable size for all future applicants that may apply on said street, or extension, and all other contingencies that may appear to the committee, a distance of inch pipe; and

We do hereby agree that if said pipe should be laid, we will forthwith make

application for the laying of service pipe to our respective premises according to the form adopted by City Council, and will pay the amount set opposite our names, annually, so that the total amount will pay 6 per cent. per annum on the amount invested by the city of Bridgeton. If these amounts are in excess of the actual rates, then we, the first to pledge the amount, shall be released proportionately for all amounts paid over and above the actual rates; and,

We do further agree that said water rates shall commence in ten days after main pipe is laid, and that our property shall be held responsible for the amount according to law.

Name.	No.	Street.	Amount.

4. Brookline, Mass.

Brookline, Mass., 191

The undersigned, owners of real estate on the way or street known as , desiring to have water pipes laid in said way, hereby severally release all claims to damages in consequence of laying said pipes and maintaining the same.

We also hereby agree to guarantee an income of at least five per centum per annum upon the cost of laying said pipe for five years, provided the revenue of water takers from the same shall not equal that amount.

5. Dover, N. H.

To the Board of Water Commissioners of the City of Dover,—The undersigned, owners and occupants of real estate situated upon in the city of Dover, N. H., hereby petition your board to cause a main water pipe to be laid through said from Street to Street; and in consideration of the laying of said pipes in the above-named by the said city of Dover, as herein prayed for, we agree for ourselves, our heirs and assigns, to take water from said pipes under the current rules and regulations made by said Board of Water Commissioners, and pay to said city of Dover at the office of said Board of Water Commissioners, on the first day of each quarter, an income equal to 5 per cent. per annum upon the cost of laying said pipe in addition to the regular rates for water established by said Board of Water Commissioners.

This agreement shall remain in force until the income from the sales of water from said pipe shall equal the cost thereof, when said Water Commissioners shall cancel said agreement, and thereafter said other parties hereto shall be assessed therefor only by the regular rates established for the sale of water.

6. Haverhill, Mass.

Agreement.

Haverhill, 191

the subscriber, being desirous that the water pipes of the

city of Haverhill be extended from said pipes on Street, thence .

do hereby guarantee to the Board of Water Commissioners of the city of Haverhill, in case they so extend said pipes, that the income from the water rates, for the water supplied through said extension, at the usual charges made therefor, as established by said Board of Water Commissioners, shall be equal to 5 per cent. on the cost of so extending said pipes, and making the needed connections.

This guarantee and obligation to continue in force for a period of five years from the time of laying said pipes, and in case the water subscribed and paid for between the above-named limits from said proposed extended pipes shall not amount to a sum equal to or more than said interest, then , the subscriber , do jointly and severally hereby agree to pay annually to the Board of Water Commissioners of the city of Haverhill such a sum of money as said aggregate water rates shall fall short of said interest on said cost.

7. Lancaster, Mass.

Lancaster Water Department.

CONTRACT FOR SERVICE EXTENSION.

In consideration of the extension of water service by the Water Department of the town of Lancaster
from to .

We hereby promise and agree for ourselves and our heirs, administrators and assigns to pay to the town of Lancaster (Water Department) during each and every year of the ten years next ensuing, a sum equal to eight (8) per cent. of the total expense of such extension.

Witness our hand and seal this day of

8. Leominster, Mass.

To the Leominster Water Board, — The undersigned request you to lay a main pipe in Street or Avenue direction, distance, size of pipe, etc., and we jointly and severally agree to and with the town of Leominster that if said pipe is laid with proper appendages, that water enough shall be taken from said pipe to the premises on the line thereof to make the regular rates therefor (exclusive of the rates for all water taken by said town for hydrants, watering troughs, sprinkling streets, public buildings and all other purposes) amount to 5 per cent. per annum on the cost of said pipe and appendages when laid.

And if such regular water rates (exclusive of the rates for all water taken by said town) do not annually amount to said percentage, we jointly and severally agree to pay to said town semi-annually, at the times when the semi-annual water rates are due, any deficiency.

In witness whereof we have hereto set our hands and common seal, each of us adopting the seal set against the first signature as our common seal, this day of 19 .

9. LYNN, MASS.

Know all men by these presents, that we, , owners of real estate on Street, so called, that, in consideration of the city of Lynn extending its water pipes to premises, hereby agree to pay a sum each year, which, in addition to the income received, shall equal five (5) per cent. of the cost of construction.

This contract or agreement to be null and void after a sufficient number of takers have been connected to said pipes to equal the required amount.

In witness hereto, set hand and seal this day of 191 .

10. MALDEN, MASS.

MALDEN, MASS., 191

To the Malden Water Board, — We, the undersigned, hereby make application for laying of a main pipe in about feet, and we jointly and separately agree that in case the water rates are insufficient to pay seven (7) per cent. on cost of laying said pipe, we will make up the deficiency.

11. MANCHESTER, N. H.

To the Honorable Board Water Commissioners of the City of Manchester, — The undersigned, owners and occupants of real estate situated upon Street in the city of Manchester, hereby petition your honorable body to cause the water pipes to be laid through street , and in consideration of the laying and extending of said pipes in the above-named street, by said city, as herein prayed for, hereby agree for

sel for heirs, administrators, executors and assigns, to take water from said pipes under the current rules and regulations made by the Water Commissioners, and pay to said city at the office of the Water Commissioners, on the first day of each quarter, an income equal to 4 per cent. per annum upon the cost of laying said pipe, in our several proportions, based upon the use made of water upon our respective estates; provided, also, that no individual party thereto be assessed less than five dollars per annum as his respective share.

This agreement shall remain in full force until the income from the sales of water from said pipe shall exceed the amount above stipulated, when the Water Commissioners shall cancel the agreement, and ever thereafter the party or parties to these presents shall be assessed therefor only by the regular rates established for the sale of water by the Water Commissioners.

Signatures of Owners of Property.

12. NATICK, MASS.

The Honorable Board of Water Commissioners of the Town of Natick, — We, the undersigned, owners and occupants of real estate situated upon

Street in town of Natick, hereby petition your Honorable Board to cause the water pipes to be laid through said street or streets, and in consideration of the laying and extending said pipes in the above-named street or streets by said Water Board, as herein asked for, we, the undersigned, hereby agree for ourselves, and for our heirs, administrators, executors and assigns, to take water from said pipes under the current rules and regulations made by the Water Board for the government of the water department, and to pay to said town, at the office of the superintendent, the amount set against our names as water rates, and we do further agree that we will continue to pay said rates semi-annually, till the said Water Board may see fit to abate, and we agree that we will pay the same rate whether we use the water or not, till the Water Board may release us.

Names.	Fixtures.	Amount.

13. New Bedford, Mass.

Guarantee.

Whereas, connecting the premises of the undersigned with the New Bedford Water Works system is not, in the judgment of the New Bedford Water Board, expedient at the present time, unless provision be made for the payment of a special rate; now, therefore, the undersigned hereby covenants and agrees with said city as follows, viz.:

In consideration of the laying of a water main pipe by the said city of New Bedford along the line of , the undersigned hereby jointly and severally agree and bind themselves to pay to the city of New Bedford, annually, in advance, on the first day of July, a sum equal in amount to 6 per cent. of the cost to the city of the above-described line of water main pipe and the laying of the same, and in addition it is hereby understood that upon failure on the part of the undersigned, or their assigns, or legal representatives, to comply with the terms of this agreement, the said city by its Water Board shall have the right to shut off the water from the service pipe on the premises of the undersigned, and, further, shall have the same control over the water, and the delivery of the same through the pipes, as it now has in respect to any other main pipe in the city.

It being understood, however, that this yearly payment is to be diminished yearly hereafter by whatever the city may receive from other takers, until the undersigned shall only be required to pay the usual water rates charged consumers throughout the city.

And upon the above-described terms only the city, by its Water Board, agrees to lay the above-described line of pipe.

Witness the hand and seal of the parties the day and year above written.

New Bedford, Mass., 191

We, the undersigned, owners of property abutting on hereby agree that in case water pipes are laid by the city of New Bedford in said said

city, and all persons acting in its behalf, shall be holden free from all claims for trespass, or damage, or otherwise, by reason of laying said pipe, and the authorized agents of said city shall be allowed by us free access to said and all necessary uses thereof, at any and all times, for the purposes of repairs, extension, inspection or otherwise, and to make all excavation thereof, and generally said city is to have all rights of uses respecting said incidental to water administration as if said was a public street; and it is further agreed that the city of New Bedford, by laying of the aforesaid water main, shall in no way become liable, or bound to accept, or keep in repair said

14. Newton, Mass.

Extensions of main pipe shall only be made when authorized by the Board of Aldermen. Applications therefor must be made upon the blanks furnished by the Water Commissioner, upon which shall be endorsed the estimate of the probable cost of the extension desired. No such application shall be considered by the Water Commissioner unless accompanied by a written agreement, binding the applicant or other responsible party to guarantee to the city annually, for at least five years, a sum equal to 5 per cent. of the total cost of the extension, but the applicant shall in no case be required to guarantee on a sum greater than the estimated cost of a 6-inch pipe. All receipts for water sold from such extension, and no other, shall be credited to the party making such guaranty as payments upon account of same.

Applications for extensions of mains through private ways or grounds shall in no case be granted unless the owner thereof executes a proper instrument securing to the city the right of permanent occupation, free from any acts of interference that shall affect the safety of the pipe, and securing to the department free right of entrance for purposes of inspection and maintenance. Nothing in this section, however, shall be construed as affecting the right of the Board of Aldermen to authorize the extension of a water main without guaranty if, upon a vote taken by yea and nay, two thirds of the members present and voting shall vote to do so.

City of Newton. Water Department.

GUARANTY FOR EXTENSION OF WATER MAIN.

Know all men by these presents, that, in consideration that the city of Newton shall lay a water main in Street, in Ward , of said city, to supply with water the premises of , the undersigned hereby covenants with and promises said city to pay to its city treasurer on demand, in advance, each year, for the term of years from the date hereof, the sum of dollars.

Said city of Newton, by accepting this instrument, agrees to repay to the undersigned at the end of each year of said term such sum, not exceeding the

amount paid to it under this agreement, as it shall receive during such year for water delivered by such main excepting any amount that it may receive for water delivered to said city of Newton.

The obligations of each water taker, however, for the payment of water rent under the provisions of the city ordinance, are not to be affected by this stipulation.

Witness hand and seal, at Newton, the day of A.D. .

Signed and sealed in the presence of

15. North Andover, Mass.

Vote of town at annual town meeting, March 9, 1907.

Article 16. *Voted*, to authorize the Water Commissioners to lay water pipes on unaccepted streets provided funds are available and the abutters give a release of right of way and guarantee a sum as water rates equal to 5 per cent. of the cost of construction.

Form of Guarantee.

Know all men by these presents, that we, , of , in the County of and Commonwealth of , as principal, and of and of , as sureties, are holden and stand firmly bound unto the town of North Andover, a municipal corporation in said county and commonwealth, in the sum of , to the payment of which to the said town of North Andover, or its successors or assigns, we hereby jointly and severally bind ourselves, our heirs, our executors, and administrators.

The condition of this obligation is such that, whereas the said principal has guaranteed, and does hereby guarantee, to the town of North Andover an income or return of not less than 5 per cent. per annum on the cost of a proposed extension of its system of water works by the laying of pipes in, over or through an unaccepted street or way known as in said North Andover, from main pipe on to a point feet on , for and during the time which said street or way shall remain unaccepted by the town and for a period of ten years thereafter; and to the end that said guarantee may be performed, has agreed, and does hereby agree, to pay or cause to be paid to the town such sums as together with actual receipts from water rates shall at all times covered by said guarantee equal 5 per cent. per annum on the said cost of construction, which said payments are to be made as and when required by the Board of Public Works of North Andover.

Now, therefore, if the town of North Andover shall construct said extension, and if the said obligors shall well and truly pay, or cause to be paid, to the town the sums secured by the above guarantee and agreement, when and as due, during the entire term covered by the same, then this obligation shall be void, otherwise it shall be and remain in full force and virtue.

In witness whereof, we hereunto set our hands and seals this day of in the year one thousand nine hundred and .

In presence of .

..............................[SEAL.]

..............................[SEAL.]

..............................[SEAL.]

16. NORWOOD, MASS.

Know all men by these presents, that for the consideration that the town of Norwood shall lay a water main in Street from present terminus to to supply water to premises in which the undersigned are interested, hereby jointly and severally covenant, promise and agree to and with said town of Norwood to pay to the Water Commissioners thereof for and during the term of ten years from the date hereof, on demand, in advance, each year, the sum of , said town of Norwood by accepting this instrument agrees to repay to the undersigned each year of said term such sum, not exceeding the amount paid by the undersigned as aforesaid, as shall be received during that year for water supplied by said extension.

This instrument is not to affect, prejudice or impair any liability or duty whatsoever of any water-taker to pay water rates.

Witness our hand and seal this day of 19 .

Witness: Signature [SEAL]. Amount.

17. READING, MASS.

Know all men by these presents, that the undersigned, in consideration of one dollar and other considerations to them paid by the town of Reading, in the County of Middlesex and Commonwealth of Massachusetts, do hereby promise and agree jointly and severally that if the said town will lay a water pipe or water main through that portion of Street in said Reading, from to and connect said water pipe or main with the water supply of said Reading and supply water in the customary manner to the premises adjoining that part of the street through which said water pipe or water main may be laid,

We will and do hereby guarantee that said town shall receive on January 1, A.D. , the sum of $ as water rates from said premises taking water from said pipe or main, and a like sum on the first day of January in each and every year thereafter until such time as there shall be water-takers enough on said street, whose water rates, at the customary charge, would equal the sum of $. And for ourselves, our executors, and administrators, jointly and severally, do hereby promise and agree to pay to said town, on demand of the superintendent of the Reading Water Works and his successors, on the first day of January of each and every year as aforesaid, such sum of money as will equal the difference between the water rates collected by the town on January 1 of each year from the said premises and said sum of $.

Witness our hands and common seal this day of A.D.

[SEAL.]

We, the undersigned, as sureties, do hereby guarantee the performance of the within agreement.

In witness whereof we hereunto set our hands and seals this day of A.D.

18. SPRINGFIELD, MASS.

To the Board of Water Commissioners of the City of Springfield, — The undersigned residents and property owners on Street (so-called), respectfully petition for a main water pipe to be laid in said street as follows:

And in case this petition is granted, and in consideration thereof, we severally hereby covenant and agree with the city of Springfield that we will make immediate application for the laying of service pipes to our respective premises, and will thereupon become water-takers, all in accordance with the current rules and regulations of said board, and that *we will pay on demand the annual amounts set against our respective signatures* until the annual water rental derived from said main pipe shall equal the sum of said guaranteed amounts; provided, however, that all such annual water rental received from ourselves or other water-takers, as per the current tariff of rates of said Board, shall first be applied toward such guaranteed payments.

We furthermore severally bind ourselves, our heirs, executors and assigns, to pay, as aforesaid, and from date of letting water into said main pipe, the annual amounts set against our respective signatures, whether the water is used or not.

Witness to signatures. Signatures. Annual amounts guaranteed.

19. TAUNTON, MASS.

In consideration of the laying of water pipes by the city of Taunton along the line of Street in said Taunton so as to allow the supplying of the premises of the undersigned with water from the Taunton Water Works, the undersigned hereby agrees to take water from said Taunton Water Works at the rates now or hereafter to be established for all takers thereof to the extent of dollars per annum for the period of years, and hereby guarantees the payment of all said rates for the time aforesaid.

This agreement is to be in force and payment of the rates aforesaid to the extent above stated is to be made as well if the undersigned shall not by himself or his tenant introduce and use the water of the Taunton Water Works in and upon his premises as if he shall so do. Said rates to begin when the Water Commissioners of said Taunton shall in writing notify the undersigned that he can be supplied with water as aforesaid by connecting with said Water Works.

Witness my hand this day of A.D. 189 .
Sign here.
Witness:

20. Waltham, Mass.

Know all men by these presents, that in consideration that the city of Waltham shall lay a water main in Street, in said Waltham, to supply with water the premises of
the undersigned hereby covenant with and promise the city of Waltham to pay to the said city, on demand, in advance, each year for the ten years succeeding the date hereof, the sum of 5 per cent. on the cost of laying said main, upon the condition that such sums as said city shall annually receive for water delivered by such main not exceeding the amount of such annual advance shall at the end of each year be repaid by said city to the undersigned. The obligations of each water-taker, however, for the payment of water rent under the provisions of law in that behalf provided are not to be affected by this stipulation.

Witness hand and seal , at Waltham, the day of A.D. 189 .

Signed and sealed in the presence of

TABLE 1.

PRINCIPAL STATISTICS RELATING TO CONDITIONS PRELIMINARY TO EXTENDING MAIN WATER PIPES, FOR MUNICIPALLY OWNED WATER WORKS.

Place.	Decision Relating to Extensions Made by	Is Guaranty Required?	Particulars of Guaranty.	Other Information.
1. Albany, N. Y.	Supt. Water Works.	No.	Water rates are assessed as taxes, at a definite rate per front foot.	
2. Arlington, Mass.	Board Public Works.	Yes.	6% on estimated cost of 6-inch pipe, for 5 years.	Deposit required in advance by vote of town.
3. Atlantic City, N. J.	Water Board.	No.		
4. Auburn, Me.	Water Commissioners	No.		
5. Baltimore, Md.	Water Board.	No.		
6. Bangor, Me.	Water Board.	Yes.	10% of estimated cost.	
7. Bedford, Mass.	Town meeting, on recommendation of Water Commissioners.	Yes.	5% for 5 years, on cost of 6-inch pipe.	
8. Belmont, Mass.	Water Commissioners	Yes.	6% of estimated cost.	
9. Bethel, Conn.	Water Board.	No.		Extensions not usually made unless Board is confident of 5% return.
10. Beverly, Mass.	Water Board.	Yes.	4% of cost.	
11. Billerica, Mass.	Water Commissioners or town meeting.	No.		
12. Boston, Mass.	Water Commissioner.	Yes.	25% of estimated cost of 6-inch pipe (equivalent to 5% for 5 years).	Whole amount deposited in advance.
13. Bridgeton, N. J.	City Council (seven members).	Yes.	6% on cost.	Extensions not made unless they will return 6%.
14. Brockton, Mass.	Water Board.	Seldom.		
15. Brookline, Mass.	Water Board.	Yes.	5% on cost of 6-inch pipe.	Bond often required.
16. Burlington, Vt.	Water Commissioners or City Council.	No.		Extension not usually recommended unless they will return 6%.
17. Cambridge, Mass.	Water Board.	No.		
18. Chelsea, Mass.	Water Board.	No.		
19. Chicopee, Mass.	Water Board.	No.		
20. Claremont, N. H.	Water Commissioners	Yes.	8% of cost.	
21. Columbus, Ohio	Director Public Serv.	No.		
22. Concord, Mass.	Water and Sewer Commissioners.	Yes.	4% for 10 years.	

23. Concord, N. H.	Water Board.	Sometimes.	4% or 5% of estimated cost	
24. Danvers, Mass.	Town meeting.	No.		Usually do not make extensions which will not earn 5%.
25. Denison, Tex.	Commissioners.	No.		Extensions not made unless revenue equals or exceeds 10% on cost of 6-inch pipe.
26. Dover, N. H.	Water Board.	Yes.	5% on cost, in addition to regular water rates, until returns from water rates have equaled cost.	
27. East Orange, N. J.	Water Board.	Yes.	10% of cost of 6-inch pipe.	
28. Enosburg Falls, Vt.	Water and Light Commissioners.	No.		
29. Everett, Mass.	Board Public Works.	Yes.	6% of estimated cost (first year only).	
30. Fall River, Mass.	Water Board.	No.		
31. Fitchburg, Mass.	City Council.	Yes.	6% of estimated cost.	
32. Foxboro, Mass. (Water Dist.)	District meeting.	No.		
33. Framingham, Mass.	Water Board.	Yes.	8% on estimated cost of 6-inch pipe.	
34. Franklin, Mass.	Water Board.	Usually.	10% on estimated cost.	
35. Franklin, N. H.	Water Commissioners	Sometimes.	5% on cost.	
36. Gardiner, Me.	Water Board.	No.		Extensions usually made when canvass shows gross income of 20% of cost.
37. Gloversville, N. Y.	Water Board.	Yes.	10% on cost.	
38. Grand Rapids, Mich.	Water Board.	Sometimes.	7% on cost.	
39. Great Barrington, Mass.	Water Commissioners	No.		
40. Greenfield, Mass.	Water Board.	Yes.	5% of cost in addition to water rates.	Guaranty required only where extension would evidently be unprofitable.
41. Hancock, N. H.	Town meeting.	No.		
42. Harrisburg, Pa.	Water Board.	No.		
43. Hartford, Conn.	Water Board.	Yes.	10% of actual cost.	
44. Hatfield, Mass.	Town meeting.	No.		
45. Haverhill, Mass.	Water Board.	Yes.	5% for 5 years.	
46. Hillsboro, N. H.	Water Commissioners	Yes.	Varies with the conditions, 6% to 10% of cost.	

TABLE 1. — *Continued.*

PRINCIPAL STATISTICS RELATING TO CONDITIONS PRELIMINARY TO EXTENDING MAIN WATER PIPES, FOR MUNICIPALLY OWNED WATER WORKS.

Place.	Decision Relating to Extensions Made by	Is Guaranty Required?	Particulars of Guaranty.	Other Information.
47. Hinsdale, Mass.	District meeting.	No.		
48. Holbrook, Mass.	Town meeting.	No.		
49. Holyoke, Mass.	Water Commissioners	No.		
50. Ilion, N. Y.	Water Board.	No.		
51. Jacksonville, Fla.	Board Bond Trustees.	No.		
52. Lancaster, Mass.	Water Commissioners	Yes.	8% for 10 years on total cost of extension.	
53. Lawrence, Mass.	Water Board.	No.		
54. Leominster, Mass.	Water Board.	Yes.	5% on estimated cost of 6-inch pipe.	
55. Lexington, Mass.	Water Board.	Yes.	7% of cost.	
56. Lincoln, Mass.	Town meeting.	Yes.	4% of cost, for 5 years.	
57. Louisville, Ky.	Bd. of Water Works.	Yes.	Generally 10%.	
58. Lowell, Mass.	Water Board.	Yes.	6% of cost.	
59. Lynn, Mass.	City Council.	Yes.	5% of total cost.	
60. Malden, Mass.	Street and Water Commissioners.	Yes.	7% of actual cost.	
61. Manchester, N. H.	Water Board.	Yes.	4% of cost.	
62. Mansfield, Mass.	Water Commissioners	No.		Extensions made only when revenue will amount to 6%.
63. Marblehead, Mass.	Town meeting.	No.		
64. Marlborough, Mass.	Water Board.	Yes.	5% of estimated cost of 6-inch pipe.	
65. Maynard, Mass.	Water Board.	Yes.	5% for 5 years.	
66. Middletown, Conn.	Water Board.	Yes.	10% on estimated cost.	
67. Millers Falls, Mass.	District meeting.	No.		
68. Milton, Mass.	Water Board.	No.		
69. Monson, Mass.	Water Board.	Yes.	4% of cost.	
70. Muscatine, Ia.	Water-Works Trustees	Yes.	6% of cost.	
71. Natick, Mass.	Water Commissioners	Yes.	Agreement to pay water rates whether water is used or not, until released by board.	
72. Needham, Mass.	Water Commissioners	Yes.	6% of cost.	Extensions are sometimes ordered by town meeting, without guaranty.

73. Newark, N. J.	Street and Water Commissioners.	Yes.	10% of cost of 6-inch pipe for 5 years.	
74. New Bedford, Mass.	Water Board.	Yes.	6% of cost.	
75. New Britain, Conn.	Common Council.	Yes.	8%.	
76. New London, Conn.	Water and Sewer Commissioners.	Yes.	5% on estimated cost of 6-inch pipe.	
77. Newmarket, N. H.	Town meeting.	No.		
78. New Orleans, La.	Sewerage and Water Board.	Yes.	8% of estimated cost.	
79. Newport, N. H.	Usually town meeting	Sometimes.	10% on estimated cost.	Water Commissioners have authority to extend pipes without vote of town when 10% guaranty is obtained.
80. Newton, Mass.	Water Commissioner.	Yes.	5% for 5 years on cost of 6-inch pipe.	
81. New York, N. Y.	Commissioner of Water Supply.	No.		
82. North Adams, Mass.	City Council.	No.		
83. Northampton, Mass.	Water Board.	Yes.	7% of actual cost.	
84. North Andover, Mass.	Board Public Works.	Yes, in case of unaccepted streets.	5% of estimated cost of 6-inch pipe, or 5% of whole cost of smaller pipe.	
85. North Chelmsford, Mass.	District meeting.	No.		
86. North Troy, Vt.	Water Commissioners	No.		
87. Norwalk, Conn.	City Council.	No.		
88. Norwich, Conn.	Water Commissioners	No.		
89. Norwood, Mass.	Town meeting.	Yes.	Definite sums annually for 10 years.	Water rates are credited but not in excess of sums guaranteed.
90. Oberlin, Ohio	Water Board.	No.		
91. Ogdensburg, N. Y.	Water Board.	No.		
92. Peabody, Mass.	Water Board.	Sometimes.	4% on cost, secured by bond.	
93. Peterboro, N. H.	Town meeting.	No.		
94. Pittsfield, Mass.	Board Public Works.	Yes.	6% on actual cost, secured by bond.	
95. Pittsfield, Me.	Water Board.	No.		Usually want to realize 10% on cost.

TABLE 1.—*Concluded.*

PRINCIPAL STATISTICS RELATING TO CONDITIONS PRELIMINARY TO EXTENDING MAIN WATER PIPES, FOR MUNICIPALLY OWNED WATER WORKS.

Place.	Decision Relating to Extensions Made by	Is Guaranty Required?	Particulars of Guaranty.	Other Information.
96. Plymouth, Mass.	Town meeting.	Yes.	4% of actual cost for 10 years.	Bond required.
97. Portland, Me.	Water Board.	In rare cases.	10% of actual cost.	
98. Portland, Ore.	Water Board.	No.		
99. Poughkeepsie, N. Y.	Board Public Works.	Yes, for extensions outside city.	Total cost to be advanced by petitioners, and returned when there is one customer to each 75 feet of main.	
100. Poultney, Vt.	Village meeting.	No.		
101. Providence, R. I.	Commissioner Public Works.	No.	Applicants must pay entire cost if estimated income is less than 7%.	
102. Quincy, Mass.	Commissioner Public Works.	Yes.	Verbal agreement to pay 6% on cost 6-inch pipe.	
103. Randolph, Mass.	Town meeting.	No.		
104. Randolph, Vt.	Water Board.	No.		
105. Raymond, N. H.	Water Commissioners	In special cases.	6% of cost.	
106. Reading, Mass.	Water Commissioners	Yes.	4% of cost.	
107. Reading, Pa.	City Council.	No.		
108. Readsboro, Vt.	Village meeting.	No.		
109. Rochester, N. Y.	Commissioner Public Works.	No.		
110. Rockport, Mass.	Town meeting.	No.		
111. Saginaw, Mich.	Water Board.	Yes.	8% of cost.	
112. St. Johns, N. B.	Committee City Government.	No.		
113. Sharon, Mass.	Water Board and town meeting.	Yes.	6% of cost for 5 years.	
114. Somerville, Mass.	Water Commissioner.	No.		
115. South Norwalk, Conn.	Water Board.	Only if without city limits.	$12\frac{1}{2}$% of cost, except office charges.	
116. Springfield, Mass.	Water Board.	Yes.	10% of estimated cost of 6-inch pipe.	

117. Stoneham, Mass.	Town meeting.	Yes.	8% of actual cost.	
118. Swampscott, Mass.	Water Commissioners	Sometimes.	6% of cost.	
119. Taunton, Mass.	Water Board.	Usually.	6% for 5 years on approximate cost of 6-inch pipe.	
120. Tisbury, Mass.	Water Board.	Yes.		
121. Troy, N. Y.	Commissioner Public Works.	No.		Property taxable for water rates.
122. Uxbridge, Mass.	Town meeting.	Yes.	4% of cost.	
123. Wallingford, Conn.	Water Commissioners	No.		
124. Walpole, Mass.	Town meeting.	Yes.	6% for 10 years.	
125. Waltham, Mass.	Water Commissioner.	Yes.	5% on cost for 10 years.	
126. Ware, Mass.	Water Commissioners	Yes.	5% of cost for 5 years.	
127. Watertown, Mass.	Water Commissioners	Yes.	10% of estimated cost.	
128. Westfield, Mass.	Water Board.	Usually.	6% of estimated cost.	Bond required.
129. Westboro, Mass.	Water Commissioners	Yes.	5% of estimated cost.	
130. Whitman, Mass.	Water Board.	No.		It is not intended to make extensions unless the earnings will pay interest on the cost.
131. Williamsburg, Mass.	Town meeting.	No.		Extensions made only when they will return 15% income.
132. Wilmington, Del.	Water Board.	Only in special cases.		For real estate "booms," etc., 5% of estimated cost; secured by bond.
133. Wilton, N. H.	Town meeting.	No.		
134. Winchester, Mass.	Town meeting.	No.		When extensions are made, assessors usually increase assessed valuation.
135. Woburn, Mass.	Board Public Works.	Sometimes.	5%.	
136. Worcester, Mass.	City Council.	No.		
137. Wrentham, Mass.	Town meeting.	Yes.	6% of cost first year.	
138. Westerly, R. I.	Water Board.	Yes.	10% of actual cost.	
139. Woonsocket, R. I.	Water Commissioners	Yes.	6% of actual cost	
140. Yarmouth, N. S.	Town Council.	No.		
141 Yonkers, N. Y.	City Council.	No.		

THE REFORESTATION OF WATERSHEDS FOR DOMESTIC SUPPLIES.

BY F. W. RANE, STATE FORESTER OF MASSACHUSETTS.

[*Read March 8, 1911.*]

Mr. President and Gentlemen of the New England Water Works Association, — The subject of municipal forests is more or less of a new idea, but I can see where forestry and water works are naturally coming together more and more. Most of you gentlemen I take it are engineers. Now, how can forestry come in along with your lines of work? I think the subject is likely to be of more and more importance as time goes on, to water-works people. I take it for granted that a great many of the works represented here are municipal works. Some of them may be private corporations, but they are all run upon practically the same lines. A few years ago, in 1908, I think it was, we had occasion in the State Forestry office to work out a plan for the city of Fall River, covering about 3 000 acres. At that time the Mayor and the commissioners and the engineer had an idea that they were going to carry the plan into effect, but for some reason or other it unfortunately has not been carried out to the extent that they had hoped it would be. They are doing something, however. They have an area of about 3 000 acres surrounding their water supply, and if any of you are interested in the report we made, I have extra copies at the office and would be glad to send them to you upon application.

At that time I read a paper before one of our scientific societies, the subject of which was "Municipal, Corporation and Private Ownership Forests," and, with your permission, I will read you a few paragraphs from that paper, bearing particularly upon the subject of municipal forests.

"The time is ripe for the development of this type of forestry. I believe all that is required at present is to agitate the subject and to explain how easily and economically it can be brought about. Our cities and towns have sprung up by the hundreds and

thousands throughout the land. Their development has been proportionate to their natural advantages. Permanency has become more stable as time has gone on until to-day finds us with municipalities ready and willing to accept and adopt almost any measure that will develop a better future and a busier center of population. Our cities and towns have been solving the problems of a permanent and efficient water supply, sewerage system, etc. Our boards of health tell us that a pure water supply is absolutely necessary to longevity of our population. Municipal forests about the drainage basins of our water supplies and reservoirs can be made not only an important factor in conserving the water supply and in improving sanitary conditions, but if put under a modern system of forestry management could be made a great economic factor in the production of wood and lumber. They may also comprise one of the great æsthetic features of the section. The time element as a factor so objectionable to the private owner in investing in forestry undertakings need not be considered here. The advent of the automobile and rapid transit has so enlarged the conceptions of the average citizen that instead of being content with shade trees and park systems, he longs for the depth and quiet of large tracts of woods, which may be furnished almost without cost through the wise forethought of our municipalities. Who has visited Germany without being impressed with the trip into the Black Forest? These very forests are not only beautiful and renowned but through their scientific treatment yield splendid net financial returns. Within walking distance from many of the cities, one can step into finer woods than can be found in our best Eastern states. Spruce and fir trees two to three feet through and all the way up to one hundred and twenty-five feet high stand on the ground as thickly as they can stand. There are acres that would cut more than one hundred thousand feet board measure.

"Municipal forests, therefore, will do much as object lessons, and their permanency and importance will assist very materially in forming a workable local, state, and national policy.

"The State Forester in Massachusetts has completed a working plan for the city of Fall River this season for a municipal forest of three thousand acres. We are working on similar projects for

three more cities at present, with still others on the waiting list. The Metropolitan Water and Sewerage Board of Boston have completed planting eleven hundred acres to forest trees about their new reservoir this fall. The city of Helena, Mont., has planted a forest of nine hundred acres. Warren Manning, the noted landscape gardener, the designer of the Jamestown Exposition grounds, etc., is an enthusiastic advocate of the broader forestry municipal development, as going hand in hand with landscape gardening.

"In a state like Massachusetts, where many park reservations like Mt. Tom, Wachusett, Greylock, Blue Hills, Metropolitan Park system, Mt. Everett, etc., have already been set aside for public purposes, if to these park systems, municipal parks, and forests be added as well as corporation and private forests, together with increased holdings for fish and game preserves, it is evident that conditions will be developed which will make our state greatly to be envied. What has been and may be accomplished in Massachusetts can be wrought with equal ease throughout the Union to a greater or less degree.

"Considering an imperative necessity for the growing of our future forest products, and considering the opportunity for business corporations and men to not only secure financial gain but bring great good to their respective communities, there certainly will be need in the future for all our well-directed acts of the present day. Is it not exceedingly fortunate that the conditions outlined do exist and that the solving of them offers hopes to the future? It is fortunate, too, that as a people we are ever ready and quick to respond to any undertaking no matter how strenuous the task, provided it will secure us benefit and reward. I have every hope, therefore, that our forestry problem will receive an early consideration at the hands of our people, and that all sections of the Union will do their respective parts in conserving the forests we already have and adopting modern methods of forest management as well as in reforesting lands unadapted to agriculture, returning them to forests for which to all intent and purposes they were created."

There has been of late much discussion on the subject of forests and their relation to stream flow and we could, if we chose, give

to you a sermon on this subject, but we have elected in this article to present to you the financial side of the question; in other words, the money profit which towns may obtain from lands which are now in their possession lying idle and unused. We believe that the time is not far distant when municipalities, like the state and nation, will take up forestry development in their midst, and that our towns and cities, like the communities of the Old World, will own their municipal forests. On the land which they have already acquired for the protection of a water supply is the place to begin.

Appended is given a list of 47 towns holding such lands, and the area held. Ten of these have sought advice from this office in regard to the management of their lands, and eight have in part carried out our suggestions, yet we are compelled to say that even these are only playing at forestry work.

No one is in a more fortunate position to practice forestry than a municipal water commission. It has as a rule no taxes to pay, the time element so detrimental to private ownership is wanting, because a municipality has, in theory at least, an everlasting existence, and the land which was bought as a protection for the water supply, from the forestry standpoint costs them nothing.

The Metropolitan Water Board has planted some 1 200 acres of land with pine and hardwoods at an average cost of $20.00 per acre. In addition, in the first ten years they have had to spend $6.00 per acre for improvement cutting, and about 25 cents per year for fire patrol. The studies of this office have shown that average land planted to pine will yield 46 500 feet per acre in fifty years, worth on the stump at present prices $465.00. Now let us balance these figures, figuring our investment at 3½ per cent., a fair average rate of interest on most municipal bonds.

		Stumpage Yield per Acre.
Cost of planting at $20 for 50 years, interest 3½ per cent. compounded	$111.70	$465.00
Improvement cuttings at $6 for 40 years, interest compounded at 3½ per cent	23.75	
Fire patrol 25 cents per year for 50 years, interest compounded at 3½ per cent	33.90	
Add to make even dollars	.65	
	$170.00	$465.00

This leaves a net balance of \$290.00 profit per acre over and above $3\frac{1}{2}$ per cent. return on the money invested, a rate of return equal to $7\frac{1}{2}$ per cent., and this based on stumpage prices prevailing at the present time, and stumpage will certainly be worth no less fifty years hence. Will you not agree with us, that a town that holds land which is lying waste and idle, owned merely to keep some one from living on it, is committing a grave economic mistake when it fails to develop it into forest?

To take a practical example of the value that forestry can be to a town, Westfield owns 942 acres of land on its watershed in Granville, of which this office made a careful study. We found that 488 acres of this area were covered with some form of woodland and 454 acres were more or less cleared, 315 of which could be planted. We made our estimate of the income which may be derived from this land, giving its value at the time of cutting, basing the amount on present stumpage values.

Types of Land.	Area, Acres.	Stumpage Value.	Ready to Cut.
Large hardwoods	33	\$2 640.00	Present.
Large pine	4	800.00	Present.
Medium hardwoods	36	3 000.00	10 years.
Medium pine	$4\frac{1}{2}$	900.00	12 years.
Medium pine and hardwoods	21	1 500.00	10 years
Culled land	160	15 000.00	25 years.
Small hardwoods	104	8 000.00	18 years.
Pine planted	315	108 000.00	50 years.

These figures when added show a net income to the town during the coming fifty years of approximately \$140 000. To arrive at the net income on the planted land we have deducted \$6 300 as cost of planting, \$1 890 for improvement cuttings, \$3 780 for fire patrol, and \$26 500 for taxes on the planted land. Taxes on the woodland (it being located in another town) would have to be paid whether forestry work was carried on or not, so they were not deducted in estimating the returns on the forested land.

We cannot in the narrow limits of this article give the processes by which we arrived at the above conclusions, but ask you to take

them on faith, assuring you that we have done our best to be conservative in our estimates, basing them, as we said before, on the present values of lumber land.

This office has given suggestions to ten municipalities that have asked for our advice, and these suggestions have been embodied in written reports, in some cases in great detail. We stand ready to help any community in the state, the extent to which we will offer our services depending a great deal on how far the town will go in carrying out our suggestions after they have been made. The only cost to the town is for the traveling expenses of the man or men who make the examination and report. Most of the other states in New England have forestry officers who will give the same service, and where they cannot be secured there are firms of consulting foresters who can be called upon to give advice without excessive cost.

Municipal Water Supply Lands.

List of Cities and Towns which have Sought Advice from State Forester concerning Forest Management of Such Lands, and Record of Accomplishments to Date. All since Fall River Report of 1909.

City or Town.	Ownership. Municipal or Private Company.	Watershed Owned. Total Acres.	Existing Woodland. Acres.	Planting Accomplished. Acres.	Plantable Area Remaining. Acres.
1. Fall River,	City	2 940.6	2 507	5	433
2. Westfield,	Town	942.0	488	20	454
3. Holyoke,	City	2 200.0	1 400	12	800
4. Leominster,	Town	94.7	(?)	12	None
5. Fitchburg,	City	400.0	250	None	150
6. Amherst,	Company	131.0	(?)	35	(?)
7. Needham,	Town	91.6	50	5	35
8. Hudson,	Town	162.0	(?)	18	(?)
9. Milford,	Company	36.0	16	None	20
10. Pittsfield,	City	1 123.0	723	None	400

Tentative List of 37 Cities and Towns having Water Supply Lands Possibly Capable of Foresting. Twenty-Five Acres and Over.

(Project as yet unconsidered.)

Areas from State Board of Health.

City or Town.	How Owned.	Watershed Acres.
1. Adams	Fire District	33.5
2. Athol	Town	301.0
3. Attleboro	Town	300.0
4. Barre	Company	35.0
5. Billerica	Town	25.8
6. Brockton	City	225.0
7. Clinton	Town	197.5
8. Falmouth	Town	82.1
9. Foxboro	District	26.0
10. Hatfield	Town	40.0
11. Haverhill	City	668.0
12. Lenox	Company	167.0
13. Lowell	City	157.4
14. Merrimac	Town	31.0
15. Nantucket	Company	32.0
16. New Bedford	City	1 682.0
17. Newburyport	City	105.0
18. Newton	City	721.0
19. Northampton	City	786.3
20. Northbridge	Company	334.0
21. North Adams	City	3 942.9
22. North Brookfield	Town	144.8
23. Palmer	Company	40.0
24. Peabody	Town	98.6
25. Scituate	Company	42.0
26. Sharon	Town	216.5
27. Southbridge	Company	307.4
28. Stoughton	Town	56.0
29. Taunton	City	110.8
30. Uxbridge	Town	64.0
31. Waltham	City	40.0
32. Ware	Town	41.0
33. Westboro	Town	90.0
34. Williamstown	Company	96.0
35. Winchendon	Town	70.0
36. Worcester	City	442.0
37. Wrentham	Town	42.5

Add to the above the ten cities and towns which have already had advice from the state forester.

DISCUSSION.

The Chairman. It gives me pleasure to call upon Mr. Nathaniel T. Kidder, president of the Massachusetts Forestry Association.

Mr. Kidder. *Mr. Chairman and Gentlemen,* — The hour is getting so late that I do not propose to give you a history or even a sketch of the history of our Association, but I do want to point out to you two or three ways in which I think it has been and will continue to be useful.

You would suppose from listening to the papers which have been read here to-day that we were all worked up in this state to a high degree of enthusiasm upon this subject, but you must bear in mind that you have been hearing from specialists. I want to say, in the first place, that the Forestry Association was largely instrumental in the institution of the office of state forester in Massachusetts. In the second place, the Association was instrumental, I believe, in introducing the tree warden into the various towns. He, in a small way, is the forester in the local community, and according to his amount of knowledge he does good.

You might further suppose, if you read over the laws of the state to-day, that there is sufficient law to regulate all these things; but you must remember that simply putting laws on the statute book does not necessarily do the work. Therefore, there is a great deal of missionary work to be done in educating the people up to these laws, and getting them not only to carry them out but to carry them out intelligently. Of course the number of officers to enforce the laws is rather insufficient, and we have got to rely a good deal on the enthusiasm of the people — and we are trying to educate them up to it. We are also trying to carry along legislation and enthusiasm together. We don't want either to get so far ahead of the other as to make difficulty, if it can be avoided. Our idea is that there is no use in putting a law on the statute books to-day which is going to be repealed next year as absolutely impractical; and so we want the people to coöperate and agree upon the general idea as to what laws are necessary.

Mr. William F. Sullivan.* Many of us have been practicing the methods that have been suggested, and put before us by the

* Engineer and Superintendent, Pennichuck Water Works, Nashua, N. H

foresters and conservationists, during the past few years. I was particularly pleased with Mr. Rane's remarks with regard to the method of harvesting, and his view that the farmer should become a lumberman. I believe that the water-works people should become lumbermen and get as much as they can out of their forests. While a forest is " a thing of beauty," it is not " a joy forever," because it has not a much longer life than a man, and it has to be cut some time or allowed to waste. I have found, and foresters must have found, that we don't get the highest financial return, or that economical value spoken of by Mr. Rane, by following the ordinary farmer methods of simply going in and slashing. I think that is a point that should be taken up by the foresters with particular reference to instructing forest owners and water-works people, who have more or less timber land, how to get the highest financial return from what they have. Of course many water works have old growths; they should cut this and plant new stock, so that there will always be a mature growth to harvest periodically. At Hartford last April* we threshed this out to some extent, and some of the lumbermen were not impressed with the idea of water works owning their own equipment, as is recommended. But I believe that where a water works owns a surplus water power it is wise, for many reasons, to put in a water-power mill. We have begun the erection of such a mill to take care of the timber that we intend to cut. We have put in the head works and expect in a short time to have a mill for ourselves and for the small farmers in the vicinity who may wish to bring their logs to us to be cut.

* Journal N. E. W. W. A., Vol. XXIV, p. 345.

PRACTICAL FORESTRY FOR WATER WORKS.

BY EDWARD SOHIER BRYANT, CONSULTING FORESTER, BOSTON, MASS.

[*Read March 7, 1911.*]

Most of the land on the protective areas which you control may be classed as agricultural land, brush land, sprout land, woodland, marsh land, and newly made land.

I believe most of you do not favor agriculture on your lands, as the plowed land is apt to be badly washed in the spring of the year. The snow, and the surface layers of the soil, melt under the spring rains before the frost has left the lower layers of the soil. This brings an objectionable amount of sediment into your reservoirs — and this is especially true where the land is heavily manured, as it must be to carry on successful agriculture. Therefore, the only agriculture possible for most of you is the annual cutting of hay lands. As the hay lands run out, their only agricultural use is for pasture, and finally, as they gradually deteriorate, they are reduced to brush land.

All of your brush land and any pastures which are yielding poor feed and small returns can probably be put to more profitable use by planting them to white pine.

Probably, in the case of those of you who control the largest protective areas, a large proportion of your territory is sprout land. Often such land has been bought by your companies, with the privilege of cutting the timber reserved to the owner. For this land there is no treatment practicable except to let it grow up with perhaps the addition of a few hundred white pine-trees per acre scattered in the openings between the bunches of sprouts.

I understand that the best practice to-day for the protection of watersheds involves the draining of all swamps so that where these are wooded they are converted into what I have termed woodland. Where there are open meadows, the draining practically puts them in the same class as newly made land. By this term I mean to designate the land which you have made by exca-

vating peat and mud from the beds of your reservoirs and piling it on the adjacent low lands. All of this newly made land, if well drained, is suitable for planting with white pine.

Woodland that is found in the protective areas of the water works of New England cities and towns consists largely of sprout hardwoods often reinforced in the older stands, to some extent, by a natural understory of hemlock or of mountain laurel.

In many cases the prevailing popular impression that it is a good thing to burn over, every year, hardwood land, and even pine land, has been further strengthened in the minds of water-works men in their effort to keep the hardwood leaves out of the reservoirs. The damage that burning over the woods every year causes is not readily apparent to men whose chief interest is not in the woods. They fail to notice that the quality of the woods as a timber-producing machine is lowered each year, and that the water runs off quicker, year by year, bringing a larger and larger amount of silt into the reservoirs. The proper solution of the leaf nuisance lies not in annually burning the leaves, but in cutting away some of the hardwood trees along the edge of the reservoirs and planting white pine, Douglas spruce, and hemlock to catch the leaves. The softwood trees do not make an objectionable amount of litter in the water and their dense evergreen foliage serves to keep the hardwood leaves from blowing into the reservoirs.

In managing your woodlands on forestry principles you have the advantage over all other forms of ownership in the fact that neither the taxes on the land nor a high interest rate are really chargeable against the forestry work. If the land were bare, and kept bare, the water companies would still have to pay taxes on it in order to protect the quality of the water. Such large stable public service concerns can borrow money at an interest rate that is far more favorable than that of any other forest owner except the state. You must also maintain patrolmen to keep your water-sheds from pollution. These men can serve without additional expense as a fire patrol, to detect, report, and extinguish forest fires. You have men on your summer pay-roll whom you want to keep with you. By giving them a job of cutting cordwood, by the cord, you can help them without raising the cost of improving your woodland. Your holdings must be relatively near large

cities. That means abundant labor, cheap transportation, and an unlimited market for your products. There is no owner better situated to practice forestry than the water companies and the municipally owned water works.

Hardwood land does not retain water so well as softwood land. The softwood trees, by shading the ground all winter, retain the snow better. Their foliage keeps the warm air under them from cooling as quickly or as much as it does in the hardwood land. The mat of fallen needles on the ground keeps the frost out of the soil. Their dense foliage keeps the wind and sun from drying off the winter's accumulation of snow at the top. When a rain or warm thaw comes, the snow melts off at the bottom and the water sinks into the soil gradually, to be slowly added to your water supply through springs instead of rushing down over the surface all at once in spring, at the very time when your reservoirs are already overtaxed by flood waters from agricultural lands farther upstream. Hardwood trees evaporate from their foliage far more water during the summer than a similar area of softwood trees.

Of all the softwoods, white pine is the most profitable to grow in this region. From the time that a plantation first reaches a commercially marketable size at from twenty to twenty-five years of age it does not cease to yield an annual increase in its money value over that of the year before of over eight per cent. until it is fifty years old.

For this reason it is desirable to plant white pine as much as possible wherever planting is advisable. It is also desirable to replace the hardwoods by pine as quickly as possible; all the more so, as the white pine is not subject to attack at all by the brown-tail moth and in pure stands it is not damaged by the gypsy moth.

It will pay you to market much of the smaller material as thinnings, and concentrate the growth of your hardwoods in the best specimens until they are ready to be made into saw timber. Then underplant the open growth of hardwood with white pine seedlings a couple of years before making the final cutting of the old harwood. When the old hardwood is removed you have a pine plantation already started which only needs the filling of a few blanks where the small pines have been killed, and a small amount of

brush cutting in about three years, and six years later, to leave it in good condition to grow until it is thirty years old.

There is only one spacing of white pine-trees that is commercially practicable and that is about six feet apart each way. If they are planted closer than that they soon become too crowded, and long before the material which must be removed in a thinning has any commercial value they become too spindly and stunted to grow at a profitable rate. The expense of close planting is also enormous. If white pine is planted at a greater distance apart than about six feet it grows limby and bushy and is subject to great damage by the pine weevil. Plantations set out six feet apart each way grow straight and with small knots at a maximum rate until they are about thirty years old, when they begin to be crowded. At that age, however, the trees which must be removed are large enough to make salable cordwood.

To sum up, therefore, I would advise you, — to keep out fire from your lands, to plant pine along the shores of your reservoirs and streams, to thin your older stands of hardwood and underplant them with pine before finally cutting them, and to plant up with pine all open areas that are not yielding a fair return. You can both make money by growing timber and at the same time improve your catchment areas.

DESIRABLE PRESSURE AT HYDRANTS.

BY E. V. FRENCH, VICE-PRESIDENT AND ENGINEER OF THE ARKWRIGHT MUTUAL FIRE INSURANCE COMPANY, BOSTON, MASS.

[*Read April 12, 1911.*]

The main purpose of a fire hydrant is, of course, to furnish water for extinguishing fires, and the problem for solution is, What is a desirable pressure to have at our hydrants under various conditions? If steam fire engines are to be depended upon, then but a few pounds' pressure may suffice to force the water out of a hydrant as fast as a steamer would use it. It is true that a somewhat higher pressure helps the steamer, but this is not essential. The cities of New York, Philadelphia, and Chicago for example have very low pressure supplies. In these cases the pipes are little more than underground canals to which the steamer gets an inlet through the hydrant. New York and Philadelphia already have special high-pressure systems for fire use only. Other cities having low-pressure supplies are considering the special high-pressure fire-fighting system, for where there are very large concentrated values, sole dependence on low-pressure water and steamers has not been considered to give sufficient protection.

If fire engines are not to be relied upon entirely, then there must be sufficient pressure at the hydrants to furnish good fire streams. The standard fire stream to-day is that discharged by a $1\frac{1}{8}$-in. smooth nozzle, with a pressure at the base of the nozzle of 45 lb., giving 250 gal. per min. This is the size of stream best adapted for all ordinary work, and for most of the work in any fire. With very large and high buildings a few larger streams are generally desirable and can be obtained by siamesing several lines of hose or, in the larger cities, by the use of 3-in. hose or occasionally larger sizes, such as is sometimes used with fire boats. In dwelling-house fires smaller nozzles can sometimes be used to advantage.

The pressure needed at the hydrant to furnish a standard stream depends on the length of hose. Two and one-half inch cotton rubber-lined hose, now almost universally used in fire department work, causes a loss by friction of about 14-lb. pressure per 100 ft. of length of hose with 250 gal. flowing. This is for hose having a smooth rubber lining. Some hose is sold in which, because of faulty methods of manufacture, or a desire to unduly cheapen the product, the rubber linings are not well backed up and a very rough interior results. Such hose may cause a loss of nearly double this amount. Of course such inferior hose should not be used. The standard fire-stream tables developed some years ago by Mr. John R. Freeman, after a very elaborate series of tests, show the hydrant pressures needed with various lengths of hose to discharge 250 gal. per min., through a $1\frac{1}{8}$-in. smooth nozzle to be as follows:

Length of Hose. Feet.	Pressure at Hydrant must be, Pounds,
100	63
200	77
300	92
400	106
500	120
700	149
1 000	192

With pressures at the hydrant maintained while the stream is flowing, of 60, 80, and 100 lb., the height of the stream as an effective fire stream,— that is, before it spreads too much into spray, — with various lengths of hose, and for moderate winds, will be as in the following table. Higher winds will very materially lessen the effective height. The horizontal reaching distance of such streams will be about 10 per cent. less than the effective height. This reaching distance is, of course, important in the case of wide buildings, the necessity to throw streams across streets, work from ladders, etc.

Plate I.
N. E. W. W. Association,
June, 1911.
French on
Desirable Pressure at Hydrants.

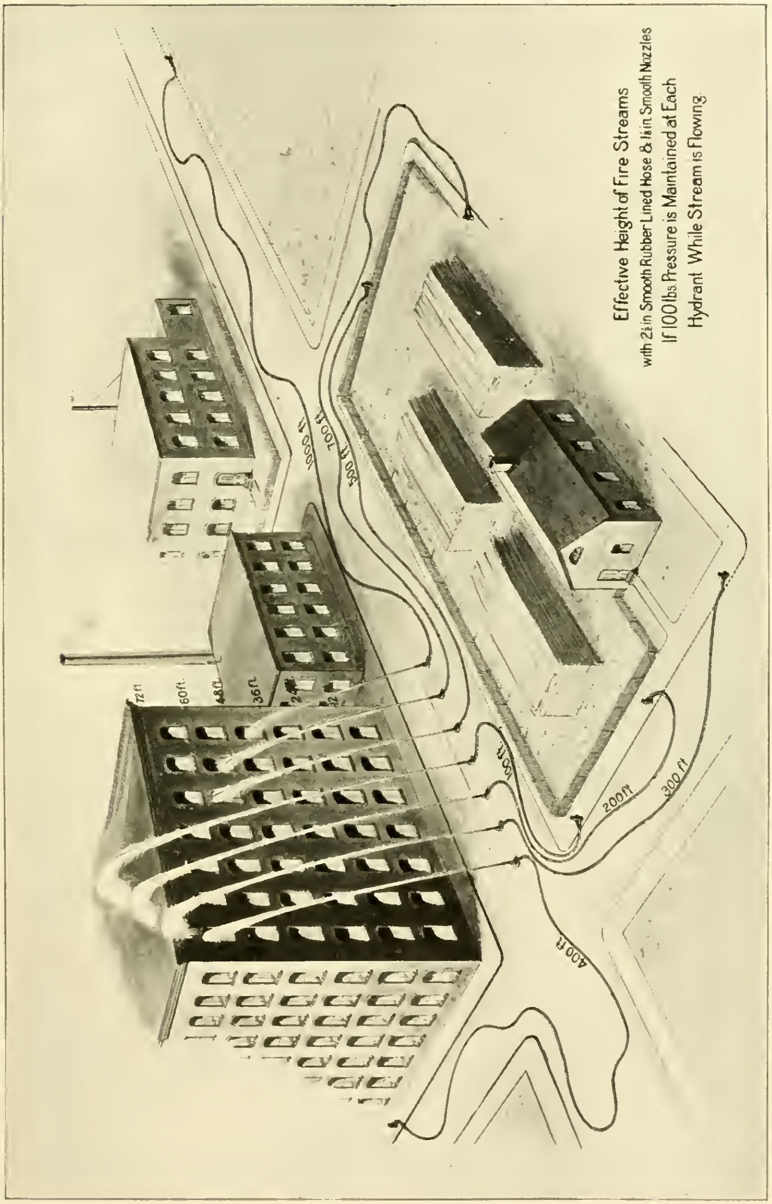


PLATE II.
N. E. W. W. ASSOCIATION,
JUNE, 1911.
FRENCH ON
DESIRABLE PRESSURE AT HYDRANTS.

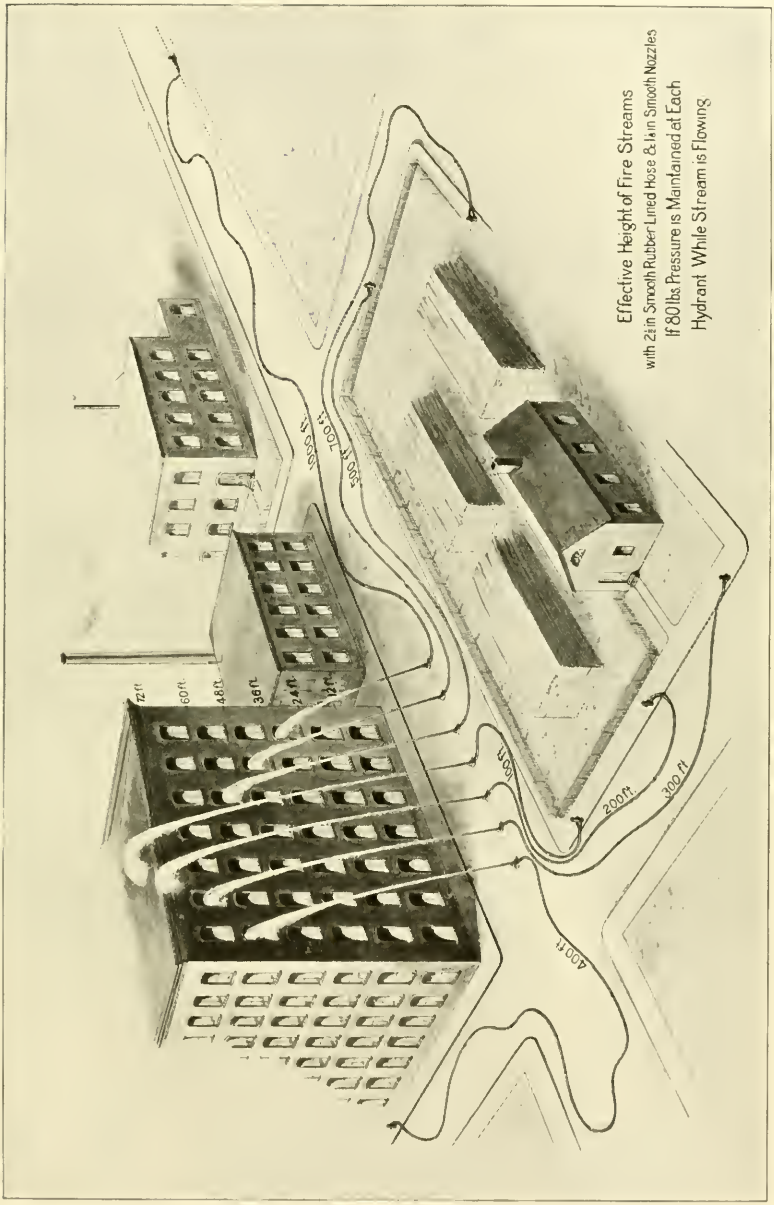


PLATE III.
N. E. W. W. ASSOCIATION,
JUNE, 1911.
FRENCH ON
DESIRABLE PRESSURE AT HYDRANTS.

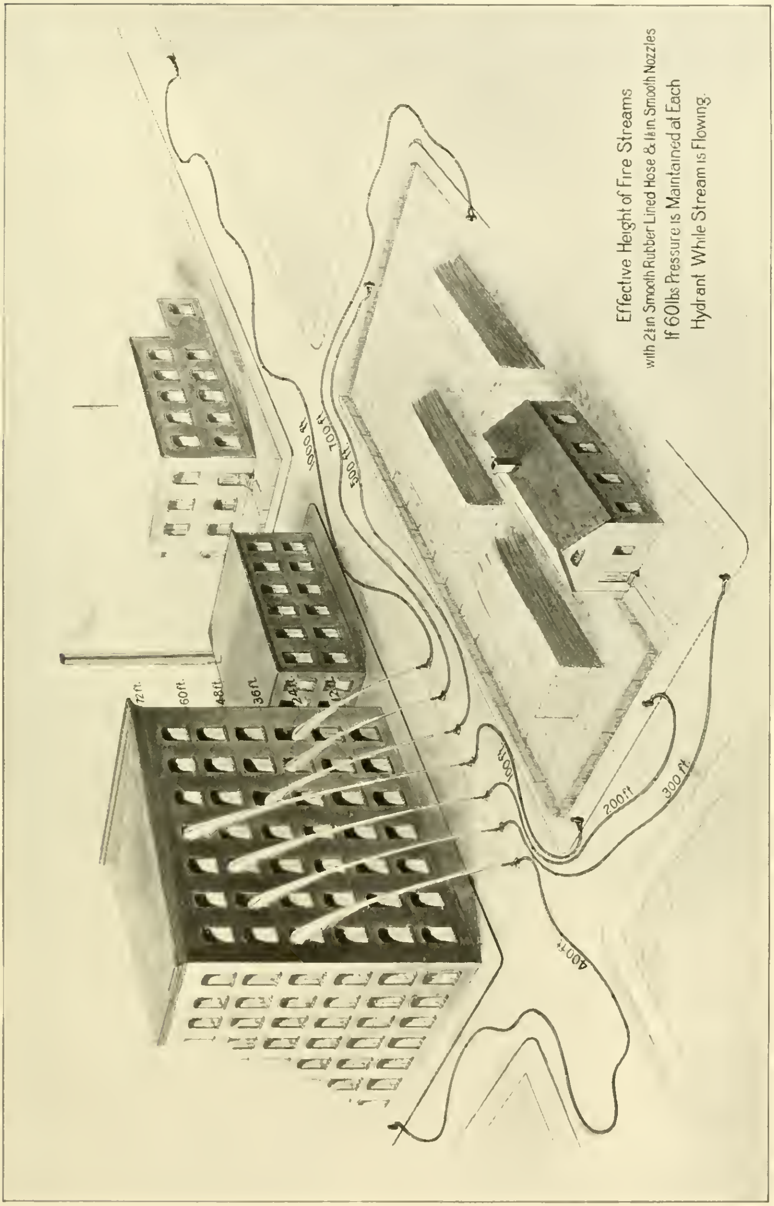
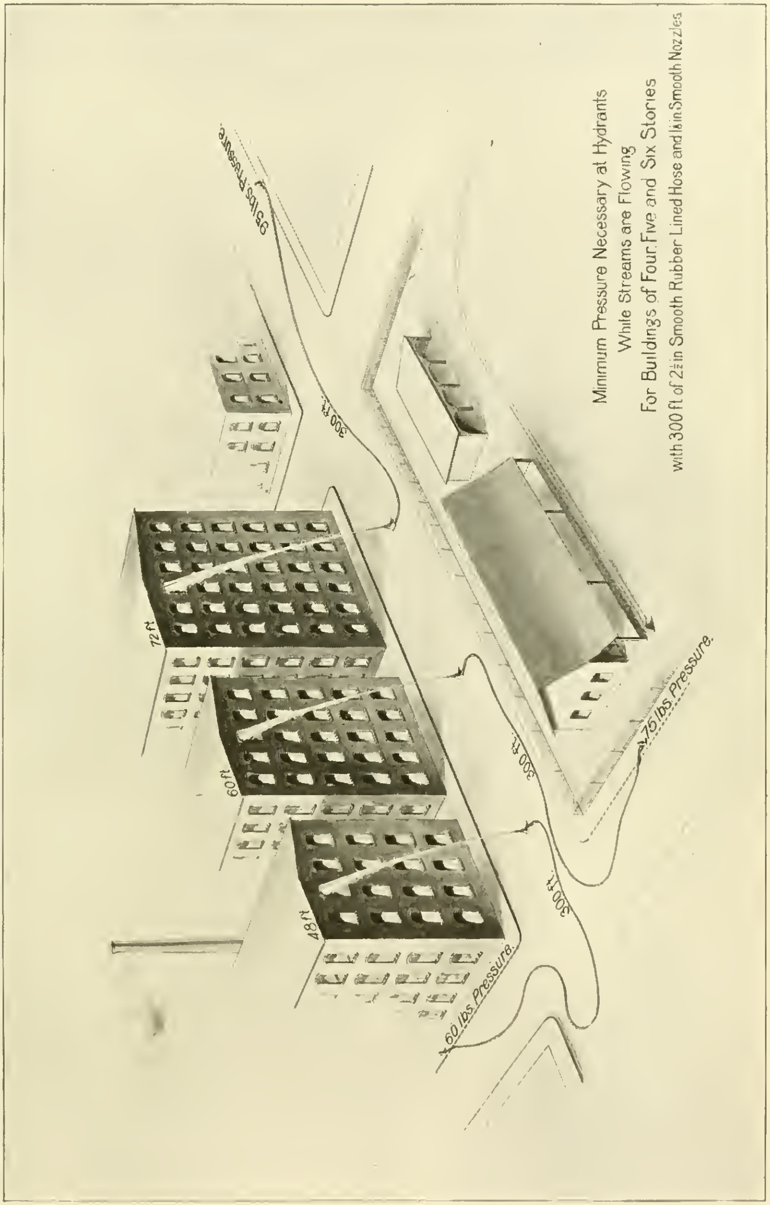


Plate IV.
N. E. W. W. Association,
June, 1911.
French on
Desirable Pressure at Hydrants.



EFFECTIVE HEIGHT OF STREAMS.

1⅛ Inch Smooth Nozzle. Length of Hose.	Limit of Height with Moderate Wind as Good Effective Fire Stream.		
	With 100 lb. at Hydrant.	With 80 lb. at Hydrant.	With 60 lb. at Hydrant.
(Feet.)	(Feet.)	(Feet.)	(Feet.)
100	88	82	67
200	82	72	59
300	74	65	52
400	67	58	44
500	62	52	40
700	53	43	33
1 000	42	34	25

This can all best be illustrated by diagrams plotted from the fire-stream tables and showing the effective height of streams thrown from the street upon a six-story building in which the height of stories is assumed to be 12 ft., bringing the roof 72 ft. above the street level. It is then assumed that the streams are supplied from hydrants located on the adjacent streets with hose lines varying from 100 to 1 000 ft. in length. In the first three diagrams the hydrant pressures are assumed to be maintained — in the first case, Plate I, at 100-lb. pressure; in the second, Plate II, at 80-lb. pressure; and in the third, Plate III, at 60-lb. pressure. This would of course mean that the mains supplying these hydrants were of such size that the pressure would be about the same at all of them.

The diagrams well show the effect of the length of hose on the height of the stream. It is, of course, true that the highest drops would go considerably higher, but the real value of the stream must be measured by its limit of height as a fairly compact mass of water, able to go through windows and strike the ceilings of the rooms with sufficient force to be thrown over a considerable area. It is this limit which was carefully determined in the making up of the standard tables, and in determining the effective heights.

For any ordinary fire fighting, even where the hydrants are spaced closely together, hose lengths of 250 to 350 ft. will be neces-

sary. This gives sufficient leeway for going around corners, into alleys, up ladders, etc., and is essential for reasonable facility in getting at the fire. It is fair to take an average of about 300 ft. as the length of hose usually needed. Plate IV has been plotted to show the hydrant pressures necessary with hose lines 300 ft. in length for buildings of four, five and six stories in height. It is seen at once that to reach the top stories under these conditions the hydrant pressures *while the streams are flowing* would have to be 60, 75, and 95 lb., respectively.

There will always be some loss of pressure in the mains, and an unavoidable loss of 2 or 3 lb. in the branch to the hydrant and through the hydrant itself. A total drop in pressure of 10 to 15 lb. due to friction in the general pipe system, including the loss into and through the hydrant, would be reasonable, but even this would require large supply mains, and a great many systems to-day show a much larger drop in pressure than this for considerable fire drafts. The ordinary pressure must therefore be enough above these pressures so that, with the friction losses which the heavy drafts of a large fire cause, the hydrant pressures will not drop below these points.

AMOUNT OF WATER NEEDED.

The number of streams likely to be required must, of course, be determined in laying out any system. For almost any condition 6 streams would be a minimum, requiring 1 500 gal. per min. As soon as the built-up section of a town or small city comes to be somewhat closely covered and of moderate area a capacity of about 10 streams, requiring 2 500 gal. per min., is needed. In our cities of medium size, such as Springfield, Lynn, and Worcester, provision should be made for 20 to 30 streams, and to give a good margin for water used by automatic sprinklers, inside standpipes, or wasted through broken connections for ordinary services, such as are sure to occur in any considerable fire, an available capacity of 10 000 gal. per min. has been generally advised and is necessary for reasonable safety, with the construction now common in cities of this general type. These quantities of water must, of course, be delivered in addition to the normal consumption of the community.

Such large amounts of water would only be needed in the congested sections, which are the high-value districts, and the pipe sizes supplying these sections must be able to deliver such quantities within the limits of about 10 lb. below the regular static pressure unless the normal pressure is carried much higher than needed, which is not generally advisable.

The total amount of water used in even large fires is not as great as frequently thought. A fire, for example, requiring 10 streams for five hours would use 750 000 gal. However, the rate of draft for fire fighting is frequently high in comparison with the ordinary consumption. Three standard fire streams discharging 750 gal. per min. use water at a rate of a little more than a million gallons a day, and 10 streams mean a rate of flow of about three and one-half million gallons per 24 hours. Pipe sizes must, of course, be proportioned for the maximum rate of demand which any fire is likely to cause.

LOCATION OF HYDRANTS.

It is also of vital importance where hydrants are to be depended upon for fire streams that they should be so near together that the whole capacity of the water supply may be concentrated on any point where the total strength of the system may be needed, and this should be possible with the use of hose lines generally not over 300 ft. in length. This would usually require hydrants much closer together than is the usual practice. Hydrants are, however, much cheaper than hose or steam fire engines. Where steamers are depended upon it is very common to use hose streams 500 and 600 ft. in length, and frequently longer, but this is undesirable, even with steamers, and a great waste of energy is absorbed simply in friction. With ordinary hydrant pressures depended upon, such needless losses cannot be tolerated.

From the above study it is evident:

> *First,* that for the general conditions found in our cities and larger towns, the ordinary static pressure at hydrants in the business and manufacturing sections, which best meet the conditions as a whole, lie between 80 and 100 lb. A pressure of 80 lb. will do very good work for smaller com-

munities; 100 lb. is needed for the general conditions of cities rather above medium size.

Second, pipe sizes must be such that the maximum amount of water needed in any section can be supplied without reducing the pressures at the hydrants more than about 10 lb. below the ordinary static pressures existing with every-day drafts.

DIFFERENT ELEVATIONS.

It often happens that there are considerable differences in elevation within the limits of one town or city. It is desirable where possible to so fix the pressure that a single system will supply all sections. This gives the simplest and most efficient arrangement of distributing pipes. In such cases, in order to get an efficient pressure in the higher portions, which would generally be the residential sections, it may be necessary to let the pressure in the lower parts be considerably above 100 lb., and this can be done without difficulty. At Fall River the pressures along the water-front range from 100 to 127 lb. At Worcester a high-service system is available in a large part of the city and the pressures range from 140 to 150 lb. At Fitchburg the pressures average about 140 lb., running up to 150 in a number of places. These are high pressures and above what would ordinarily be recommended for a general public service, but they have been maintained and used by the regular consumers for years without special difficulty. The arrangement of the new water supply for Springfield, which gives 140 lb. throughout the business district, with pressures of 75 to 80 lb. for most of the residential section, is an excellent example of different levels supplied by one system. It provides excellent fire protection and will undoubtedly prove satisfactory from practically every standpoint.

Experience shows that there is no serious difficulty in maintaining pipes and fittings within the limits of the above pressures. Further, that it is possible to change from a lower pressure to a materially higher one without any really important difficulties. With reasonable care there is no need of any great increase in leakage or in breaks, especially when starting new. Where the

water has to be pumped it would cost somewhat more to raise it to the higher elevation, but with modern efficient pumping machinery the difference is not great and the whole cost of pumping is relatively small in comparison with other costs which our water departments must meet.

ADVANTAGES.

The first and principal advantage from hydrant pressures of 70 to 100 lb., and sometimes higher, comes from the immense improvement in fire protection which is secured above that obtainable with low pressure and dependence on fire engines. Each hydrant becomes practically the equivalent of the average steamer; lines of hose can be attached to a hydrant and water put on a fire much more quickly than if a steamer has to be set, connected, and put in operation. If the progress of a fire makes it necessary to shift hose lines this can be done much more expeditiously than if a heavy fire engine has to be moved. When a conflagration threatens to sweep our cities, as at Chelsea and Baltimore, hose carts can quickly lay lines in different sections, making it possible to surround and drown a fire which would get away in the time lost by moving steamers and getting them in operation.. Radical improvements in construction would be the best way to stop conflagrations, but this is a remedy which will come but slowly, and until our standard is greatly improved there is nothing which would give the probability of checking a conflagration so well as good pressure available at every hydrant supplied by pipes of such size that each hydrant could at any moment furnish two, three, or four efficient fire streams. Strong water supplies also very much increase the value and efficiency of sprinkler equipments.

A town or city with such a water supply can make a very material saving in the cost of its fire department over what would be necessary with low-pressure water and sole dependence on steam fire engines. In such a city it would in many cases be necessary to keep only a few steamers in service and in some cases none at all. Such steamers as were needed would usually respond to only a few boxes in the more hazardous sections, so that in the main these steamers would be practically in reserve, and could be main-

tained at a minimum cost. Figures obtained in two cities under good average conditions showed the cost for maintaining fire apparatus to be about as follows:

Yearly cost of maintaining a hose wagon about....................	$4 000
Yearly cost of maintaining a steam fire engine and a hose wagon....	8 000
Yearly cost of maintaining a steam fire engine without a hose wagon,	4 600
Yearly cost of maintaining a steam fire engine in active service beyond what it would cost to maintain it in reserve about......	3 400

These figures include the cost of the men, the horses, repairs, and all ordinary expenses, together with a proper amount of interest, and sinking fund charges for the house or the part of the house occupied by the apparatus in question.

It will be seen from these figures that a very material saving in annual cost is possible, and when this can be done with an increase in the efficiency of the fire depatrment the gain is most satisfactory. This saving would generally more than pay for any additional cost in the annual charges for the water department, and would in some cases also pay considerable interest and sinking fund charges on the cost which might be entailed in changing a low or moderate system for one of good pressures, such as are believed desirable.

SPECIAL HIGH-SERVICE SYSTEMS.

Such a system using separate pipes from those of the ordinary water works, and designed exclusively for fire fighting, with water supplied at pressures which may go as high as 200 or 300 lb. may be justified in ten or twelve great cities of the country, where enormous values are concentrated, and warrant the maximum protection. It is not believed that such special systems are warranted in the great majority of our cities. The cost entailed would often be ample to put the usual system on a good pressure basis which would give most efficient fire protection. When this is done the whole city gets the benefit, whereas in general the special high service must be limited to a few districts. This method gives greater simplicity, efficiency, and probably in general at lesser cost. If it is coupled with a judicious requirement

for automatic sprinklers in dangerous buildings which may be fire breeders, more will be accomplished than by any special high-pressure fire system which could ordinarily be provided.

GRAVITY SUPPLIES BEST.

A gravity supply of water is the best thing for fire purposes. A reservoir of good capacity or a large standpipe gives a reserve supply already stored at the higher elevation and available to meet any sudden large demand. Water thus stored is, we may say, capital on hand, giving strength to meet any emergency, whereas the best pumping equipment must depend on the right action being promptly taken when special demand arises, and there must be very large reserve capacity to meet possible heavy calls which would come but rarely.

We found in studying this problem at Lynn that it was now possible to build very large standpipes of concrete, and these may well be used in those cases where there is not a suitable site for a large reservoir which would be generally preferable where feasible. Standpipes holding as much as 8 000 000 gallons can be built, and reputable concrete men are ready to guarantee them. We considered two sizes, one 125 ft. in diameter by 90 ft. in depth of water, another 150 ft. in diameter by 60 ft. depth of water. Such standpipes can be built at a cost of \$100 000 to \$125 000; the capacity of each would be about 8 000 000 gal.

Twenty years ago tanks for fire purposes in our factories of 5 000 gal. were common. To-day steel tanks of 50 000 to 100 000 gal. and steel trestles from 75 to 125 ft. in height are regular productions, like any other commodity, and are commonly used where tank supplies are necessary. In the same way the development of our water-works systems should go beyond the small standpipe of 200 000 or 300 000 gal. to standpipes of several million gallons, or to larger reservoirs wherever they are available.

Such water supplies delivered at good pressures will give our communities greatly increased fire protection, and in general stronger and more satisfactory water-works systems.

DISCUSSION.

THE PRESIDENT. Mr. French's statement that in many cities money can be better spent in improving the regular water-works system to make it sufficient for ordinary fire requirements than in putting in a special high-pressure system is most interesting and important. I have had the feeling for some time that the policy outlined was a wise one for many of our cities, and I have encouraged it in several cases.

Mr. French also made an interesting statement to me privately before he spoke, to the effect that if such automatic sprinklers as are required in the factories insured by Mr. French's companies had been installed in a certain factory building in New York City, the fire which occurred in it, with a dreadful loss of life, a few weeks ago, could have been entirely prevented.

Most of you know of the work of the National Board of Fire Underwriters. They send their men to test your water supply systems, find out where they are weak, and tell you how they may be improved. I think some of you have an idea that, whatever size of pipe you propose to lay for your mains, the insurance people will recommend one size larger.

We are fortunate in having with us Mr. Booth, representing the National Board of Fire Underwriters. I will ask Mr. Booth to explain this and other matters to you.

MR. GEORGE W. BOOTH. *Mr. President and Gentlemen,* — I am sure there is some misunderstanding in regard to what your President has just said, because I looked over the plans of the Springfield distribution system this morning, and I am sure I would not recommend any larger pipes. I was in some doubt before Mr. French read his paper as to whether I was going to be able to agree with him on all points, but after I have heard him read it I do not remember that there is anything with which I cannot entirely agree. There are some points, however, to which I should like to call attention.

I suppose there is nothing which has been the subject of more debate among the engineers of the National Board of Fire Underwriters than this question of hydrant pressures. The debate has been not so much on the possibility of securing good protection

where good pressures exist, but whether it was fair to expect, or whether it could be expected, that the fire department could and would make such use of those pressures as to secure effective results. There are several reasons why a system having a pressure of 80 to 100 lb. to the square inch does not always give such results. Perhaps one of the commonest reasons is that the mains are not large enough to maintain that pressure under heavy draft, which, after all, is the real test of a system, and the idea on which it should be designed; or because, where direct pumping is depended on, there isn't sufficient pumping capacity. Not all cities have been as courageous as Springfield in securing high pressures. The ordinary pressure, where direct hydrant streams are depended on alone, of from 80 to 100 lb. will very likely not be maintained under heavy draft, but will drop, perhaps, 20 or 30 lb.

Another reason why a system nominally able to give good service does not give it, is the poor hydrant distribution. So far as my inspection of hydrant spacing in Springfield goes, I think that that criticism could not be made with justice here. But in most cities, especially outside of New England, the length of some of the hose lines which it is necessary to use in furnishing the number of streams desired will run up as high as 800 or 1 000 ft., and these diagrams that Mr. French has prepared show you what kind of a stream can be secured through such hose lengths, even under the best conditions. Moreover, since a conflagration, which demands the greatest supply, is apt to occur under adverse conditions, perhaps high winds or other conditions which detract from the efficiency of the system, there is still further reason for not getting as good results as should be obtained.

Another point that is sometimes of considerable importance is the loss of head in the hydrant. We have found cases where the loss of head has been 20 or 30 lb. And that is not to be wondered at when you take into account some of the hydrant connections. I think one of the worst I can remember is a case where the hydrant was connected with the main by three $\frac{3}{4}$-in. pipes. Naturally you wouldn't expect to get very much water.

As concerns hydrant pressures on separate fire main systems, most of these systems provide for an ultimate pressure of 300 lb., but I think the maximum has never been used. The highest I

can recollect was during three simultaneous fires in New York, when they were carrying a pressure of 225 lb. at the pumping station, and as they were delivering something over 30 000 gallons a minute, it was rather necessary that a high pressure should be maintained. What we have in mind is, that while, perhaps, under the best conditions 100 lb. will give you good fire service, we feel safer if there is something more back of it, for use if necessary under adverse conditions.

I am able to agree with Mr. French on another point, and that is that there are, perhaps, only ten or a dozen of the biggest cities in the country which really stand in need of a high-pressure system such as has been put in in Philadelphia and New York. I believe if you will look over the reports of the National Board you will find in a great many of them that reference is made to the fact that money can be spent to better advantage by bolstering up the old systems and increasing the pressures than by putting in separate systems.

The President. This Association some years ago adopted a uniform hose coupling, which is described in one of our Journals,* and is a very vital matter, because when there is a big fire in one of our cities and we want the fire engines from other cities to come and help us, if the connections for different hose are different, as they all used to be, it is a very bothersome matter, and may greatly interfere with or entirely prevent advantage being taken of assistance. Mr. Griswold is here to-day and has something that he wants to show to the members of the Association in that line.

Mr. F. M. Griswold.† A committee was formed some years ago with the idea of proposing a thread which would be universal on $2\frac{1}{2}$-in. hose couplings. In going over the past work in relation to standardizing the thread, we went back to 1873, when the chief of the Fire Department of Cleveland, Ohio, proposed a standard. For some reason, I don't think from any scientific knowledge on his part, he picked out a thread of $3\frac{1}{16}$ in. outside diameter over the male thread with $7\frac{1}{2}$ threads to the inch. It is an odd combination, but, as has been said by a great many people, it has proven to be a mechanical anomaly. For instance, you cannot

* Journal N. E. W. W. A., Vol. XX, p. 348.

† Of the Home Insurance Company of New York, N. Y.

put a 6 and 7 thread together, nor can you put a 7 and 8 thread together, but you can use in a $7\frac{1}{2}$ female thread the 7 and 8 male thread of the same outside diameter, even if they have not been machined to make a better fit. In other words, a full $3\frac{1}{16}$-in. outside diameter male of 7 threads will go into the $7\frac{1}{2}$ female of the same diameter sufficiently for an emergency coupling, and with the pressure that may be put on the soft metal with a spanner it can be run down to within about one thread of a complete connection.

This city of Springfield has just demonstrated the practicability of changing from a snap-coupling, — the Universal, I believe it was. If you drop a heavy snap-coupling on a stone pavement, it is liable to jamb the edges, so that you cannot make a good joint, and every section will leak at the coupling. Here in Springfield they have changed the couplings on over 1 350 fire hydrants and over 22 000 feet of hose, so that this city has the National standard coupling. This coupling does not have any one's patent behind it, it is absolutely an open device with nothing in it for anybody, and anyone who knows how to make a coupling can make it.

It is one of the easiest things in the world to-day to use a 7 or 8 thread within the range of a $3\frac{1}{16}$-in. outside diameter or even of 3 1/32 in. or 3 1/64 in. where the inside diameter of the hose coupling itself is not greater than $2\frac{1}{2}$ in. Of course, if you increase the inside diameter, you reduce the shell, and if you knock anything off that shell you weaken it so that, perhaps, in drawing the hose you may break it. But so long as the interior is $2\frac{1}{2}$ in. or less, and your outside diameter is $3\frac{1}{16}$ in., you may very readily and very serviceably change a 7 and an 8 thread to fit the $7\frac{1}{2}$ female thread. It is not necessary to remove the nipple from the hydrant, nor the coupling from the hose, to accomplish these results. A tap and die that is designed to the number of threads you are operating on will do the work of reduction, which may be accomplished by the firemen themselves at odd times.

This is the sixth year, I think, that this committee has been at work. We were very pleasantly told, when we were appointed, that we might accomplish something in twenty years, but I am glad to say that inside of twenty months we had all the leading

authorities, — the American Water Works Association, the New England Water Works Association, the International Association of Fire Engineers, the National Association of Fire Engineers, and many municipal societies, — all approving it, and now this city has given us a demonstration of the method by which the National Standard may replace the non-standard coupling. I can report to-day that a new record which our committee has just issued shows that there are seventy-eight places from which we have learned that the change from non-standard to standard couplings has been made, — that is to say, either by adopting the standard for new installations, or by trimming down their 7 or 8 thread to fit the $7\frac{1}{2}$-in. female. I imagine if everybody from whom we have heard in relation to couplings had taken the trouble to tell us whether they had changed or not, we might have one hundred and seventy-seven on the list. No water-works superintendent or fireman who has charge of a system need feel afraid of making this change when the opportunity offers. It is a matter of little expense, and it absolutely helps you in getting assistance from your neighbor when you need him, and helps your neighbor when you go to help him. You recall, perhaps, that at the time of the Baltimore fire the New York Fire Department went down, but it was absolutely of no service to Baltimore until it got to the open water of Jones's Falls, where it could make suction. Previous to that their suction hose was tied to the hydrant outlet by wire, and a horse blanket tied over that, so that the engines could get some water, but not much. When they got down to where they could get open water, they did very efficient work.

I trust that you will not forget that this is as much the baby of the New England Association as it is of the National Fire Protection Association, and that our committee will help you wherever it is necessary, and will be very glad to.

The President. I hope that every member of the Association will use his influence in every proper way to secure the adoption by our cities of this Standard thread, which the Association has adopted.

Mr. George A. King.* There was one point, Mr. President, which Mr. Booth touched upon which it seems to me should be

* Superintendent of Water Works, Taunton, Mass.

considered by all of us in designing our arrangement of hydrants and their connection with the mains; that is, the loss of pressure due to friction in the connection from the main through the hydrant. I think that the design of the tee connecting the main, and the size of the connection with the hydrant, are worthy of more consideration than we have been giving them, at least in our city.

There is one other point which I wish Mr. Booth might give us some information upon. I have examined, I think, from seventy-five to one hundred reports of the Board of Fire Underwriters, and in every one of them they speak of the desirability of keeping a record of the gate inspections. In the reports which I have examined I think half a dozen cities are mentioned as keeping a record of the gate-valve inspections, but I have written to every one of those places, and I have got from only one a form in which that record is kept, that is, Omaha, Neb. Utica, N. Y., has sent me a sketch of what they propose to use, and those are the only two places from which I have obtained any idea of what system is employed, and, so far as I have been able to learn, they are the only places in which any record is kept of gate inspections. I would like to know what the Board of Underwriters would like to have done in that line.

Mr. Booth. There are not many places, perhaps, where they do keep such a record, but I know of perhaps half a dozen, and I will be glad to look the matter up and send you what seems to be the best form.* The reason for keeping such record is, of course, pretty evident. It is well illustrated by a report which came in from one of our large cities a little while ago, that out of, I think, about 7 000 different gates inspected, 70 or 80 were found closed altogether, probably because the men who had operated them had gone away and forgotten all about their being closed. Besides those 70 or 80, there were a large number which were partly closed. If a record is kept of every operation of a gate, it isn't nearly so likely that the man who closes it, perhaps to repair a break in the main, will go off and leave it closed.

I think it is not nearly as much of a task to keep the record as you may think. It is kept in a number of places. I know it is kept in New York, at least on the high-pressure system. I haven't

* See pages 276 and 277.

in mind just what the places are, and cannot tell just what the form of the record is.

Mr. Morris Knowles.* I take it, Mr. President, that there is no serious disagreement between Mr. French and Mr. Booth in regard to the necessity of some things other than high pressure; further, that Mr. French will agree with Mr. Booth that it is necessary to have the mains adequate and the sources of supply sufficient, whether from pumps or reservoirs. Mr. Booth has touched upon one other point which I think needs emphasis, and that is the distribution of the hydrants. Generally, the lack of a proper distribution, or lack of a sufficient number of hydrants, may be attributed to the method of paying for fire protection service. This may not always be true in municipal supplies, at least where nothing is paid by the city itself to the water-works' finances for the use of hydrants, but it certainly is true where the municipality is supplied by a private corporation.

As you all know, the usual basis of payment for fire service provides an annual rental at so much per hydrant, and the number of hydrants is determined by the choice of the municipality. In making the original contract, they may have started out with a certain minimum number of hydrants. As the city grew, and most of our cities have grown very rapidly, they may not have changed the contract, at least so far as the minimum number is concerned. Consequently, the municipality, desiring to keep the price as low as possible, has made an effort to keep the number of hydrants at the minimum.

It seems to me the compensation for fire service should be differently arranged than is customary. Let it be recognized that payment should be based upon the ability of the plant to furnish sufficient water at good pressure, and not merely upon the cost of a certain number of hydrants. The number of hydrants should not be made the basis of payment, any more than should the quantity of water consumed for fire purposes be considered as a proper measure of the fire service rendered. It is possible and practical to estimate the value of this service in any given case. This cost may be paid in several ways, as a lump sum, or per mile of main, or in any similar manner which may be thought advisable,

* Consulting Engineer, Pittsburg, Va.

but the important point is to have it understood that the real basis is the protection afforded and not merely the number of hydrants in use — then, and not until then, will the present incentive to unduly restrict the number of hydrants be removed.

Another thing I was very glad to hear Mr. French mention was the desirability of not having dual supplies unless there is some special condition. I think this is in the same class with the so-called dual supply for domestic water. That question frequently comes up in this way: "Why is it not wise, instead of having all the water pure, simply to have a small supply of good, pure water for household use, and let the main supply for general uses be as it may?" Outside of the question of danger to health in having a dual supply, where people are always prone to drink from the wrong one, there is the question of the economy of the system. Very seldom it happens that it is economical to build two systems. And I think the same is true as regards fire protection; it is rarely true that it pays to build two different systems, unless the situation is very unusual, like a congested and hazardous section in a large city, and I was glad to hear Mr. French mention this. It is more economical to have a unified and simplified system than to have one that is complicated.

Mr. George A. Stacy.* This discussion as to high service and fire protection is certainly an important subject. When the Marlboro water works were constructed, in 1883, we had a pressure varying from 16 to 142 lb. for our domestic supply and for fire purposes. That condition prevailed for ten years. In the upper levels of the city, where some of our largest factories and buildings were, perhaps a third of them, we had only 30 lb. pressure. Since the public water supply was introduced, we have been dependent upon hydrant pressure entirely for fire protection. Previous to that time we had the old hand engines; we have never had a steamer. As the factories grew in size, and the buildings were more numerous and larger, the insurance companies insisted that we should either have a steamer or improve the pressure on the system. The matter was taken up, and it was finally decided to erect a standpipe with three miles of separate mains to cover the higher levels of the city. That brought the pressure for fight-

* Superintendent of Water Works, Marlboro, Mass.

ing fires up to 60 lb. on the higher levels, and we carried the stand-pipe system to the point where we had 50 lb. pressure at the hydrants from the reservoir. The reservoir is of $5\frac{1}{2}$ million gallons capacity.

Our high-pressure system was designed to deliver ten streams of 250 gallons a minute, with a loss of pressure of from 8 to 10 lb. The system was tested near one of our largest factories, and on a four-way hydrant we put a pressure gage on one nozzle, and we took three streams out of the others, and we took eleven streams in all from the system. When they were all playing, the gage showed a maximum loss of $7\frac{1}{2}$ lb. We used $1\frac{1}{8}$-in. nozzles, except one which was $1\frac{1}{4}$ in.

In the district covered by the stand-pipe system, where we had 30 lb. pressure we now have 80, and that has been sufficient for any work that we have had to do. There is no question but what a gravity system is the ideal system for fire fighting, if the pressure is sufficient; and we feel to-day in Marlboro that we have a system that answers every requirement.

There is something which has not been brought up here, which I know to a certain extent affects the capacity of our mains, as they grow older; and that is the filling up of the mains by tubercles. We had one 4-in. line, about 1 600 ft. long, and a barn took fire out at the end of it; they had to lay about 450 feet of hose The initial pressure was 65 lb., and the result was that they couldn't get a fire stream near enough to that barn to wet it. We replaced this line with 6-in. pipe, and I don't think the 4-in. line had a capacity of a 2-in. pipe. I never saw a pipe so filled up in all my experience.

One 4-in. line that I replaced with a 6-in. pipe, I found perhaps not over 10 per cent. reduced in capacity. I think the amount of tuberculation will vary to a certain extent in different localities and under different conditions.

I believe, as has been said here to-day, and I have always advocated it, that hydrants are a great deal cheaper than hose; and those of you who have been in the fire department, and have had practical knowledge of the work, know that you can get two streams on a fire with 250 or 300 ft. of hose as quickly as you can get one with 500 ft., and there will be higher pressure at the nozzles.

On one of our streets about 700 ft. long and situated on one of the higher levels, where there is only 25 lb. pressure and where there are only two-story houses, well separated and on one side of the street only, we had 150 ft. of hose connected to a hydrant at the end of the street and found that there was pressure enough to send the water clean over the building, the men standing at a place where they would naturally stand if the fire was pretty warm. When, however, we connected 500 ft. of hose, there was not pressure enough for effective work. We put in, therefore, another hydrant 400 ft. from the first, and now there is sufficient pressure and volume to control any fire that would naturally occur there. Wherever it is possible to obtain it at a reasonable expense, I think that the most effective and most satisfactory service is from a direct pressure gravity supply; and I believe that with ample pipe capacity, where such service can be obtained for a reasonable sum, you have the ideal fire service.

Mr. Walter H. Richards.* There is just one point I should like to make, that I think has not been touched upon, — the practical business point of view. The insurance companies come before us and ask us to make these improvements. Who pays for them, who gets paid for the improvements, and who receives the benefit? Is it the people, or is it the insurance companies? I have never heard of a case, when a change has been made of this kind, where the insurance companies have lowered their rates. It seems to me it is up to them to do a little something in that line. If the community pays for these improvements, the community should get the benefit of them. If the insurance companies keep right on charging the same rate, the people don't get any benefit at all, but it simply puts more money into the pockets of the insurance companies. That is all there is to it.

The Manufacturers Mutual has been for years coming before this Association and suggesting these improvements and expenses in addition to the regular expenses of the water-works system, but there is never any lowering of rates on property of the whole community. They come as special pleaders for a special benefit to themselves, and not to the city as a whole. Now, in all improvements of any kind, whether in water-works systems or anything

* Engineer and Superintendent Water and Sewer Department, New London, Conn.

else, we always want to know whether it is going to pay, and it seems to me that these requirements do not pay anybody but the insurance companies.

Mr. Stacy. In regard to hose, we have been fortunate in buying very good hose from way back in the old time when we used leather hose, — and anybody who has had to handle that kind knows what that means, — up to the present. My experience has been that when we have had a large fire we have had the most trouble with hose, and that happens largely for the reason that the old hose is kept on the racks and of course deteriorates to a certain extent from age, whether it is used or not. Now, it may be that the chief has gone to the city government and said, "We want some more hose." The question is asked, "How much hose have you got?" And he replies that they have so much. "Isn't that enough? How much do you ever use?" "But," he says, "some of this hose is getting old." So the committee of the city government goes around and looks at it, and it looks all right to the members of the committee, and it is hard to make them understand, although they are honest enough, the necessity of getting any more. We figured out that a certain amount of hose was needed every year to keep the supply up to the standard, but we couldn't make the powers that be believe that always. Now, when there is a large fire, you pull down your old hose, and just as you get to work, away it goes, and you put in another line, and away that goes, and then everybody is up in arms and says that the department is no good and the whole system is rotten. But we know that the fire department is not to blame. There won't be much trouble if the hose is tested, say, once in every two years and the worthless hose thrown out and enough new purchased to keep the supply up to the standard. The men who are at the head of the thing, who really have the authority to purchase hose, may be honest in their opinion. They see the hose, it looks all right, and that is enough for them. It is just the same as in the case of a hydrant; it looks all right, although there may be three $\frac{3}{4}$-in. pipes running into it. That doesn't make any difference. The committee don't want to spend any money on it because it looks all right, and they are honest enough in their opinion. A certain per cent. of new hose should be purchased every year, and then it

can be determined pretty close when that hose is going to give out.

Mr. Booth. I should like to be able to give some assurance to the gentleman who complains that he gets no reduction in his insurance rates, but the National Board has no control over that matter. There is another side to the question, of course, and that is the benefit it is to a merchant or manufacturer to have no fire on his premises, or if one occurs to have it put out quickly. The way the insurance companies look at it is that it is hardly fair to expect them to pay for everything. I see that Mr. Stacy does not agree to that.

Mr. Stacy. I think there ought to be at least a fair division.

Mr. King. There is one point which Mr. French referred to upon which I would like to know if he can give us any more information. He spoke about the roughening up of the inside of hose. Doesn't that occur with old hose, and isn't it in some respects worse than to have the hose burst, because you are expecting a larger flow through the hose than what you can get because of the roughness of the inside and the greater amount of friction?

Mr. French. *Mr. President,* — what I had reference to was not so much a change in the condition of the hose due to age as the difference in smoothness of lining, depending on how the hose is made. Possibly a word or two may be of interest in that connection. In making rubber-lined hose, the cotton fabric is first finished, and as that is woven, the interior, before the rubber lining is put in, would be rough due to the fact that the yarn used is rather large and that there is a space between each strand. Now, it is possible to back up a rubber lining by a proper packing of soft rubber, so that when you put in the final lining the spaces between the strands are filled up, and it remains smooth. If this is not done properly, if there is a desire to cheapen the hose, the filling up can be omitted and the lining can be simply cemented on the inside, and when you look through it it may look pretty smooth. But when a pressure is put on, say of 100 lb., that forces the rubber lining, which, of course, is very elastic, into the spaces between the strands of the yarn and makes a rough interior.

In order to determine the exact effect of this action, this matter was taken up by Mr. John R. Freeman some years ago. Hose of

various kinds was tested and it was found that in a good grade of hose the loss was about 14 lb. for every 100 ft. of length with a standard stream flowing. With another grade of hose, which was just as easily bought and probably at about the same price, the loss was 25 lb. in 100 ft., nearly twice as much as in the good grade. In order to show this graphically, short lengths of hose were taken, a coupling put on each end, and a cap put on one end and the hose then filled with plaster of Paris.

Before the plaster hardened a cap was put on the other end and the hose subjected to a pressure of from 80 to 100 lb., and the pressure kept on while the plaster was hardening. This forced the lining into the position that it really is in when the hose is carrying water. Then, after the plaster of Paris had hardened, the hose was cut open and the plaster cast removed. Plate V shows two pictures of hose where this was done, — Fig. 1, a very rough interior, judging by the plaster cast, and Fig. 2, a very smooth one.

Now, it is perfectly possible to get a reasonably smooth lining if it is insisted upon, and it is easy enough to test it, either by this method, which is very easily applied, or possibly better by taking several lengths of hose and measuring the friction loss through them, and thus showing the manufacturer right off whether or not he is giving you a lining that is reasonably smooth.

In answer to Mr. King, it is probable that as hose gets older, the lining, which may have been fairly good in the beginning, tends to crack and to get rough. I have not heard that point brought up before, but I see no reason why there shouldn't be some increase in the friction of hose due to this cause. I imagine, however, before that would get to be very bad, before the increase of friction would be really serious, that the hose under pressure would probably give way and leak so that you might have to throw it out.

While we are on the subject of hose, it is unfortunate that hose manufacturers have for fire department hose taken a position that for the present prevents the adoption of the kind of specifications which ought to be adopted. I have no doubt that eventually a broader view will prevail, and all interests will get together on the question. We found many years ago a great deal of very poor hose in the mills, and specifications were made over fifteen years ago for our factory fire hose. These have been pretty well lived

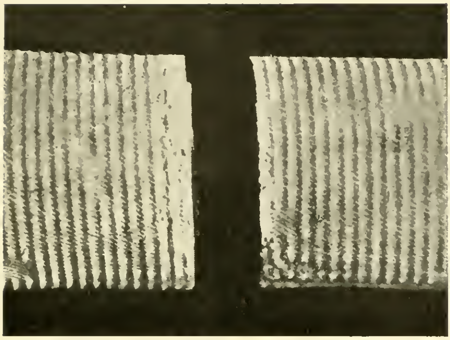


FIG. 1.
PLASTER CAST, SHOWING INTERIOR OF HOSE WITH ROUGH RUBBER LINING.

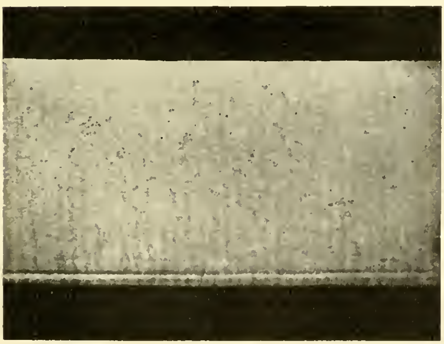


FIG. 2.
PLASTER CAST, SHOWING INTERIOR OF BEST RUBBER-LINED HOSE.

up to, and to-day we get hose in which breaks are quite rare. There is no trouble in making hose so it will stand all the pressure needed, and with rubber linings that will be durable. And right there is one of the most vital questions in hose buying. If the rubber compound is made properly, and the right amount of good rubber put into it, the life of the hose will be from seven to ten years, we will say, while a hose a little bit cheaper in first cost is very likely to go to pieces in three or four years by the cracking up of the rubber lining. It is immensely better economy to pay fifteen or twenty cents, or even more, per foot and get a hose which will last two or three times as long, than it is to buy the cheaper hose and then have to replace it absolutely in two or three years, as well as running the risk of its bursting, as Mr. Stacy says, at the time of a fire. Rubber analysis has got to a point where it is possible to tell what kind of rubber one is getting.

It is a very good plan to test all fire department hose yearly under good pressure, — not a pressure sufficient to damage it, but a pressure sufficient to throw out the poor lengths; and this is really an advantage to the hose because rubber is rather improved by wetting it occasionally. The fabric should be thoroughly dried after the test.

I was interested in what Mr. Richards said about rates of insurance, and I think a word ought to be said about that. I happen to represent insurance interests where, being on the mutual plan, if there is any saving the assured get it, because they get all there is left after paying the losses. Now, it is a fact that it will generally cost seven to ten times as much to insure an unprotected plant as a protected one. The owner does get that benefit, and, what is more, the cost of the protective equipment, which the owner puts in at his own expense and not at the expense of the town or city, is usually all recovered by the mere saving in insurance cost in less than five years. One couldn't get a better investment, because he not only gets his money back, but after it comes back, he saves money very fast in insurance charged; then, what is more important than all that to any prosperous manufacturer, the danger of burning up a business when making money is almost eliminated, and most of our American manufacturers are making money one way or the other most of the time.

I am not acquainted with the general insurance business in cities and towns, our work being confined entirely to manufacturing properties having special protection; but I believe there is not the slightest question but that practically, though one may not be able to figure it instantly, in any case when better fire protection is provided there is a saving in insurance cost. If rates do not immediately go down, they are prevented from going up, because in the long run the only way an insurance company of any kind, whether mutual or stock, gets any money is by collecting it from people. There is no inexhaustible treasure box from which to pay losses, — the money must be collected in one way or another. When property is burnt up it has to be paid for by the people who live in the community, but that community is sometimes spread over a broad area, so that one place helps another. No city in this country can say that it is so much better than some other that it ought not to contribute, for while one place may be paying something out to-day, to-morrow the money may be rolling back to it. Every improvement in fire protection and water supply that reduces fire loss is sure in the long run to mean a saving to the people of the country.

There is another point that Mr. Knowles made that ought to be emphasized. We meet it again and again in connection with automatic sprinklers. To have as a basis of payment for fire protection, when payment is made, a certain price per hydrant or per sprinkler is the best way to discourage good fire protection. You induce a town, when they have to pay so much per hydrant, to try to get along with about half the hydrants that they ought to have. Now the fact is that one hydrant, costing possibly all set \$40 or \$50, will last for years. If that hydrant saves 200 or 300 ft. of hose at approximately \$1 a foot, it saves a good many times the value of the hose that would have to be used. Moreover, hose, even the best quality, will have to be renewed every seven to ten years, while the hydrant will last indefinitely. You can easily make figures which will show that you can save more money by putting in hydrants for the fire department than in any other way, when it means a real saving in the amount of hose that has to be carried. Charging by hydrant or by sprinkler is a direct discouragement of putting in all you ought to have, and really the only

proper basis, as Mr. Knowles has intimated, is to charge for what is really given, that is, for the amount of fire protection that is available. It is hard, however, to measure that. We had a committee of the New England Water Works Association some years ago, and I happened to be a member of it, that tried to get up some method of doing this, but did not succeed in getting anything which was workable. But there must be some way which can be developed, which will be broader and better than the old way, and which will bring a proper return, when a charge is a proper one to make, but still will not discourage the very thing that is desirable to encourage.

Somebody mentioned a trouble we are meeting a good deal, and that is an apparent carelessness in pipe laying, which results in getting stones or gravel in the pipes. We have had some cases where on the opening of a number of automatic sprinklers in a rather severe fire the extra rush of water swept along a lot of rubbish, which evidently had collected in the pipe, probably getting in at the time when the pipe was being laid, and obstructed a number of sprinklers. I have seen repeatedly in mill yards, where we were testing the hydrant system, one after another, $1\frac{1}{8}$-in. nozzle, plugged with stones, and the men would have to shut off the line, unscrew the nozzle, and take the stones out, and sometimes it was necessary to knock them out, they would be wedged in so hard. That is a thing which in some cases has given us a good deal of concern.

Mr. King brought up the question of valve inspection which is a very important matter. In our factory properties, which are all equipped with automatic sprinklers, there are many hundreds of valves, because each riser has to have a valve, and very often, especially in the older plants, there is a valve at each floor. Our inspectors find a good many valves closed, and where so much depends on the automatic sprinklers we have found it necessary to take this matter up specially. In spite of the fact that this point is being watched with the very greatest care, and that those plants are under the supervision of men of a good deal of ability, we find every month that it takes two or three sheets to merely list the closed valves found in factories in the United States and Canada, and give a brief account of the cause of each one. It is

usually the case that the valve was shut for something and forgotten. We have made the suggestion, and many of the mills have agreed to it, that the mill should have a man, very often the master mechanic, or some man under him, generally a member of the factory fire brigade, go around at least once a week and try every valve on the plant. We have gotten up a simple form that gives a place for each valve, and we advise the mill owners to tag each valve, either with a brass tag with a number, or sometimes a number painted on the valve. Then a man takes the list and goes to each valve, and as he notes its condition he checks it up on this list as "open," "shut," or in whatever condition it is in. In some of the larger plants, where the owners are very exact about the thing, they have arranged a system of punching, and a man punches a tag attached to the valve, showing the condition he finds it in, and the dates, and then after awhile those cards go to the manager. This makes it necessary for the man to go to the valve to make his record, but is too elaborate, except for some of the very large plants.

As we test the water in the factory yards once a year, we find every summer a number of valves in city connections or in city streets closed. We find them in this way: Our men are instructed never to touch or to do anything with the public valves without first taking the matter up with the water-works superintendent, so that they can work absolutely together; but we can go into the factory yard, and first notifying the water department, when they ask it, and open up several streams. We may have found last year that four streams drew the pressure, we will say, from 80 lb. to 60 lb., and this year four streams draw it from 80 lb. to 40 lb., which shows right off that there is something wrong. Then the matter is looked up, and again and again a street valve will be found partly or entirely closed.

We had a very glaring case of that in one of our plants, where there were several connections into the mill yard. It was a plant which needed automatic sprinklers very much, being a rather hazardous sort of old construction. Our man in testing got very little water, and in looking up the matter found that there was an obstruction in one of the connections. That was removed and it was supposed that everything was all right, but the mill manager,

not being satisfied, tried another test and got unsatisfactory results. An investigation showed that the trouble was due to the fact that two connections came into the yard fed by one branch from the city main. In that branch was a closed valve, which had been closed, apparently, for some work on the street, though this was in one of the well-managed water-works systems. Now, that mill for several weeks between the visits of our inspectors had a water supply on its automatic sprinkler system sufficient for only a few sprinklers, when it really was a plant which needed a most ample supply. This does show the need, which Mr. King brings up, of looking out for valves in city streets, just as much as watching the factory equipment; and I do not see any reason why it would not be possible to get up a blank on which, possibly, the valves would be numbered, in accordance with a map in the superintendent's office, and perhaps the different sections of the city divided, and then once or twice a year, or as often as necessary, have a man go around and try the valves and check them up. If they are numbered or located in some way he is not so likely to miss a valve as if he is merely told to go out and try all the valves. You don't know whether he tries them all or not, — he himself really doesn't know, although he may think he does, — but if the work is laid out in some systematic way, there will be much less chance of missing a valve. I think that could be done with the very greatest advantage.

Just one point more with regard to hose couplings. I happened to be in Fryeburg, Me., once when a part of the village burned, and the fire was a thrilling sight as it went almost unchecked along the beautiful village street. A steamer came by train from Portland, fifty miles, and when it arrived, several hours after the fire had started, there was the greatest cheering and encouragement. The Portland firemen rushed into the town, pulled their hose wagon along and laid out several lines, and everybody thought that now the fire was going to be extinguished. The steamer went to hydrant, but it couldn't connect. I can see the picture to-day of that steamer standing there in the village street, with all its polished metal work, and the hydrant there, but no means of getting the two together, and the fire going on and on until it finally was checked by the feeble means that the town department had.

While that isn't half as much a story as the story of the Baltimore fire, yet, having seen it, it makes a much more graphic picture for me; and the idea that in this age neighboring communities, which would like to help each other, are prevented from getting together by the fact that a few screw threads won't fit, seems perfectly ridiculous.

Mr. Coggeshall.* Mr. President, I haven't any doubt but what very full instructions are given to all the mill people, as Mr. French says, and that they have a fine plan, with everything set out on it, but, nevertheless, we occasionally have a telephone call to the office asking where such-and-such a gate is, or what such-and-such a gate controls, so I think there is still a chance for a little more missionary work in that line.

Mr. French. There is no doubt about that, but still a good deal is being accomplished, Mr. Coggeshall.

Mr. Geo. W. Booth (*by letter*). The attached forms were adopted by the New York Department of Water Supply for use on the separate fire main system, after a study of the forms in use in various cities; these forms have proved very satisfactory and it is planned to extend their use to the domestic system as soon as clerical provision is made to take care of it, but as this means 25 000 or 30 000 of both valves and hydrants, it is something of a task to prepare for it.

I have asked for suggested changes to these forms, both from some of our National Board engineers and from the engineers who have used them, the only suggestion being a widening of some of the columns on the " Valve Record " sheet.

Each valve and each hydrant should have a number, and these numbers and the general location of the valve should be shown on key maps. The detailed locations may be shown either by sketches on small sheets, with ties to fixed objects, or in tabular form, with reference distances either to curb lines or to street lines. It is believed that the latter method is preferable where curb or property lines are well defined.

The " Field Report " sheet is to be turned in each day by the foreman in charge of each gang, and to show a complete record of operations of any kind. A " Valve Record " sheet is provided

* Superintendent of Water Works, New Bedford, Mass.

for each valve in service and is kept in the office and filled out up to date from the field reports turned in by the foreman.

It may be that local conditions will call for some changes in the form, but the general idea appears to be satisfactory.

FIELD REPORT.

No. ....
(To be filled in at Main Office)

Station Blotter No. .... Station .... Date ....

Work Done ....

....

....

....

Line Shut Down from ....o'clock ....19........to .... o'clock ....19........

List of Gates and Hydrants Disturbed or Other Work Done.

Size or Type of Valve or Hydrant.	Location.	Repairs, Etc.	Condition in which left.

Date .... **VALVE RECORD** .... Record Number ....

Location of valve ....

On .... inch main in .... Street ....

Description (upright, on side, geared, ungeared) ....

.... inch valve .... screw .... turns to open full. Opens right/left. Screw extends when closed .... inch

.... inch bye pass .... screw .... turns to open full. Opens right/left. Screw extends when closed .... inch

Distance from operating nut to street surface .... Valve set in .... Type of cover ....

Made by .... Date made .... Date set ....

Field Report No.	Shut Down	Opened	Reported Out of Order	Reported Poor Condition	Reported Good Condition	Foreman

PROCEEDINGS.

Special Meeting.

Hotel Kimball,
Springfield, Mass., April 12, 1911.

Mr. Allen Hazen, President, in the chair.

The following members and guests were present:

Members.

S. A. Agnew, G. W. Batchelder, J. F. Bigelow, C. A. Bogardus, I. W. Brooks, Edmund Brown, G. A. P. Buckman, T. J. Carmody, R. C. P. Coggeshall, M. F. Collins, H. R. Cooper, F. H. Crandall, G. E. Crowell, J. A. Fitch, E. V. French, Albert S. Glover, R. K. Hale, F. E. Hall, C. N. Harrub, A. R. Hathaway, Allen Hazen, F. T. Kemble, Willard Kent, A. C. King, G. A. King, H. M. King, J. J. Kirkpatrick, Morris Knowles, E. E. Lochridge, Daniel MacDonald, S. H. McKenzie, W. A. McKenzie, Hugh McLean, A. E. Martin, W. E. Maybury, G. F. Merrill, H. A. Miller, O. E. Parks, E. M. Peck, A. E. Pickup, W. H. Richards, Henry Roberts, H. W. Sanderson, J. E. Sheldon, A. F. Sickman, G. A. Stacy, L. A. Taylor, J. L. Tighe, J. H. Walsh, F. N. Northrop. — 50.

Associates.

Anderson Coupling Company, by Charles E. Pratt; Chadwick-Boston Lead Company, by A. H. Brodrick; Chapman Valve Manufacturing Company, by H. L. DeWolf, V. N. Bengle, H. D. Storrs, Robert Shirley; Darling Pump and Manufacturing Company, by H. H. Davis; Hersey Manufacturing Company, by Albert S. Glover; Henry R. Worthington, by Samuel Harrison; Fred A. Houdlette & Son, Inc., by M. S. Kahurl; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, Arthur R. Taylor; Charles Millar & Son Company, C. F. Glavin; National Meter Company, by J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Pittsburg Meter Company, by F. N. Northrop; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall. — 19.

Guests.

James P. Steele, C. A. Cooke, Marlboro, Mass.; E. C. Colters, S. A. Allen, and John L. Hyde, Westfield, Mass.; C. L. McNeil, Torrington, Conn.; T. J. Lynch, T. J. McCarthy, Hon. John J. White, mayor, of Holyoke, Mass.;

H. E. Bodurtha, Agawam, Mass.; T. A. Collins, Boston, Mass.; Wm. J. Trevithick, Middletown, Conn.; C. A. Goodhue, Thompsonville, Conn.; Edward H. Lathrop, mayor of Springfield, Wm. H. Daggett, C. M. Waterbury, A. L. Fletcher, H. M. Lee, C. A. Crocker, S. L. Haynes, I. B. Hinkley, Thomas Greeley, Frank L. Worthy, Springfield, Mass.; C. M. Woodward, W. H. Sanburn, West Springfield, Mass.; G. W. Booth, F. M. Griswold, New York City; C. C. Dyer, Wm. F. Aiken, Thomas L. Lawler, Greenfield, Mass.; Dr. P. L. Brown, G. F. Farmer, and James J. Fitzgerald, Springfield, Mass. — 33.

The President. Gentlemen, all things come to Springfield sooner or later. A few weeks ago, when some of the Tech Alumni of Springfield got together and offered a site for the Massachusetts Institute of Technology, if it would come to Springfield, because there appeared to be great difficulty in getting a suitable site in Boston, I remember seeing a cartoon in the Boston *Globe* representing Springfield as trying to pull away the Institute of Technology and Boston trying to fasten down Bunker Hill Monument and Faneuil Hall so that those could not be taken. When our Springfield friends asked the New England Water Works Association to come here, however, I don't think any of us wanted to nail the Association down to Boston, we were all glad to come. I have the pleasure now of introducing to you Mayor Lathrop.

Mayor Lathrop. This introduction has been a little bit sudden. I was lying back luxuriating in the expectation of hearing a formal speech, out of which I could acquire at least a bit of watery education. I didn't suppose that your friend, the President, was to terminate his address so quickly. I never apologize for being present most anywhere. But let me tell you in confidence that my being here is a sort of conspiracy between my engineer and my associate water commissioners, who know something, and inasmuch as they, in the various performances of our municipal functions, help me over places where I need assistance, there is no reason in the world why I shouldn't obey their summons whenever and wherever it comes. These public functions that are incident to the office of mayor are not generally observed in the daytime. Most always our public functions are nocturnal, and in a measure it is safer than when we perform them in the daylight; but inasmuch as water is the pervasive element in your profession,

as also the dominating liquid of the feast, I find that this occasion is absolutely safe.

There is no occasion for extending a formal welcome to you gentlemen here. Before coming I was a little bit doubtful as to any peculiar capacity I might have in the line of extending a welcome to you in a proper way, and I have not been able to get any special inspiration in the way of information with reference to your professional accomplishments or really as to the scope of your endeavors and the definite results that you are illustrating so vividly and so practically throughout the municipalities not only of the Commonwealth but of the country. We have been suffering from hard lines within the last two years, and I don't know but it is attributable to the fact that you people didn't come here earlier. We haven't had water enough, until within the last few months, notwithstanding that we have been in the habit of making pretty large municipal boasts with reference to our accomplishments and our quantities in the way of a water supply. Now, however, by reason of a fortunate combination, perhaps, of the elements, we are getting to a position where our engineer can with propriety boast of the capacity of the reservoir and assure an anxious people that there will be water enough — except that we can't let our neighboring municipalities have any.

You know that we have a number of suburban neighbors who have a habit of clamoring quite largely and vociferously when they want anything badly. They have got the most peculiar habit of hollering for water, instead of the other thing, and we have got in the way of being a little careless when that demand comes at our backdoors. So we sit by in a sort of self-congratulatory condition that we can inundate ourselves when we desire it, and if we are a bit malicious in our enjoyment, we can say, "Good people, why didn't you get into gear earlier? That is what we did, and now you see what our results are." We can say to them, "If you suffer for water now, just think what the ultimate consequences may be, when you enter upon a more extended existence."

However, levity aside, gentlemen, this is not my opportunity, nor is it my intention to occupy much of your time. I think I interpret most correctly and thoroughly the sentiment of the

people of this municipality in saying to you that not only is the city pleased at your attendance here, but that we have a sort of a grateful feeling that runs towards a bit of benediction that your coming here is a sort of an assurance that whenever we need help, if we want water, we shall know where our ultimate resort is. We have superintendents, engineers, and commissioners. Some of the commissioners don't know much, — I am one of them, — but I am buttressed so well by my associates that I am at least a little bit entitled to brag on such an occasion as this for their benefit. So I say that when we ever get *in extremis*, we shall know the sources of resort when we want our relief, because if our own instrumentalities fail we can reach out to you and say "For the Lord's sake come and help us and keep us out of the condition that Long Meadow and West Springfield are already in." Now, let me say to you, gentlemen, notwithstanding that this is a daylight excursion, which is a little bit unnatural, especially when we eat and drink, I, in the name of the municipality, bring you the largest possible and the warmest welcome. [*Applause.*]

THE PRESIDENT. We thank you, Mr. Mayor, and it gives me special pleasure to hear you speak about some things that I have been saying to you in regard to selling water. You see, gentlemen, I have been telling the mayor that he now, having a good water supply and plenty of it, might fairly divide with some of his neighbors who need it, the only proviso being that he shall get good value for everything that he sells. He has been a little worried for fear that he might sell too much of it, but I have told him not to worry about that, but to go ahead and sell all he can.

THE MAYOR. Whether we can deliver it or not?

THE PRESIDENT. That is just the point, for some of us here know how to build works, and we can build him all the works that he needs, so that he can sell all the water he wants to.

The subject of our meeting to-day is fire protection, and that brings to mind that some years ago, when the new water supply for Springfield was being talked about, there were two fires here happening very close together, one the City Hall and the other the church on the hill, in which two lives were lost; and those

fires had a good deal to do with pushing forward the adoption of a new source of supply which has since been constructed. Springfield has been growing rapidly and is being built well. If every one would build as good buildings as this hotel, which I have seen to-day for the first time, there wouldn't be as much need for large quantities of water for fire protection as there now is. The day is coming when substantial construction of this kind will take the place very largely in our cities of the more flimsy and inflammable construction of the past, and the fire protection requirements in the future I look forward confidently to as being on a very different basis from those of the present time. But at the present time we have our cities built up as they are, and urgently need more adequate fire protection against the dreadful disasters of which we have too many examples. We are favored to-day in having with us Mr. French, a man who has had a great deal to do with the development of the insurance end of this work; and one of the most impressive facts of that work is that the insurance people have learned how to prevent fires. It seems to me that their work in preventing fires has come to be, perhaps, from the standpoint of the community, much more important than what was, I suppose, the original idea of compensating people for loss by fire.

Mr. E. V. French, vice-president and engineer of the Arkwright Mutual Fire Insurance Company, of Boston, then presented a paper on "Desirable Pressure at Hydrants." He was followed by Mr. George W. Booth, who is connected with the National Board of Fire Underwriters. Mr. F. M. Griswold spoke about the National Standard Hose Coupling. Mr. R. C. P. Coggeshall read an extract from a letter from his son, who is located in business in Yokohama, Japan, giving a description of a fire there and the way it was handled by the Japanese fire department. Among others who spoke were Messrs. George A. King, Morris Knowles, Walter H. Richards, and George A. Stacy.

The Secretary presented application for membership, duly recommended and endorsed, from George W. Booth, East Orange N. J., with National Board of Fire Underwriters, New York City; Thomas Fleming, Jr., Pittsburg, Pa., hydraulic and sanitary engineer, Pennsylvania State Department of Health; Joseph H.

White, Birmingham, Ala., Construction Department, Tennessee Coal, Iron and Railroad Company; Thomas J. Lynch, Holyoke, Mass., treasurer Holyoke Water Board; F. M. Heermann, Dorchester, Mass., engineer and special inspector for the Associated Factory Mutual Fire Insurance Companies; Henry Pike Letton, Lincoln, Neb., civil engineer, at present taking special graduate work in sanitary engineering at Massachusetts Institute of Technology; Alton D. Adams, Worcester, Mass., constructor of electric plants and appraiser of water powers.

On motion of Mr. A. E. Martin, the Secretary was directed to cast one ballot in favor of the admission of the applicants, and, he having done so, they were declared duly elected members of the Association.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at Hotel Kimball, Springfield, Mass., at twelve o'clock, Wednesday, April 12, 1911.

President: President Allen Hazen, and members Michael F. Collins, Morris Knowles, William E. Maybury, John J. Kirkpatrick, Richard K. Hale, and Willard Kent.

Several applications were received and recommended for admission, namely: For membership, Alton D. Adams, lawyer and consulting engineer, Worcester, Mass.; Harry P. Letton, sanitary engineer, Lincoln, Neb.; F. M. Heermann, engineer and special inspector, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.; Thomas J. Lynch, treasurer Holyoke Water Works, Holyoke, Mass.; Thomas Fleming, Jr., consulting engineer, Pittsburg, Pa.; George W. Booth, chief engineer, Committee on Fire Protection, National Board of Fire Underwriters, New York City; Joseph H. White, Construction Department, Tennessee Coal, Iron and Railroad Company, Birmingham, Ala.

Voted: That the Secretary be and hereby is authorized to dispose of copies of papers to members, at his discretion, at fifty per cent. discount from the established price.

Voted: On motion of Mr. Hale, that the Pittsburg Metal Products Company be authorized to reprint Mr. Kuichling's paper on "Steel Pipe for Water Works," on giving proper credit to the New England Water Works Association.

Adjourned.

WILLARD KENT, *Secretary.*

New England Water Works Association.

ORGANIZED 1882.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE PROPOSED ATLANTIC INTRA-COASTAL WATERWAYS.

BY EDWARD PARRISH, C.E., NEWPORT, R. I.

[*Read March 8, 1911.*]

At the Norfolk Convention of the Atlantic Deeper Waterway Association last fall, President Taft said that Speaker Cannon of the House of Representatives "could not see the use of building a canal within a biscuit's throw of the ocean." He then added that the reason was because he was from Illinois, and he thought that if he had him on the *Mayflower* off the mouth of Chesapeake Bay, with a good southeaster blowing up from Hatteras, and could then run him up to the mouth of the Potomac, he would appreciate the difference between the open ocean and a protected waterway.

Therein is clearly indicated an important reason for an intra-coastal canal, and I shall endeavor to enlarge somewhat upon it, and present for your consideration a few others.

It seems hardly necessary at this time to undertake any elaborate demonstration of the difference in cost, under conditions of fair competition, between rail and water transportation. I think the great economy of the latter form, where it can be secured, is generally conceded. A short time ago I was impressed by the sight of a train of cars, 50 in number, probably averaging 20 tons each (there were none of the large 40- or 50-ton cars in the train), carrying coal up the valley of the Pawtucket River, 1 000 tons being hauled by two locomotives. This load was one third of the

cargo of a single barge, which was one of three brought into Providence Harbor by a single tug.

The matter of water transportation has been highly developed in the ore-carrying trade on the Great Lakes, representing, with the coal-carrying trade on the Mississippi and Ohio, phenomenally low cost per ton-mile, amounting in the former to about .69 mills and in the latter to .376 mills.

These rates are largely due to the peculiar circumstances of the trade to which they apply, and can hardly be regarded as fair indices of what might be expected under usual commercial conditions existing along the Atlantic coast; but they both are evidences of the results that can be accomplished by an intelligent adaptation of all available means to a specific end. In the case of the ore-carrying on the Lakes, there was available a certain depth of water, and the vessels were built for it and in such a manner that the cargo could be both loaded and unloaded with a minimum delay; the terminals were designed with the same end in view and supplied with the most modern machines for handling the cargo — and in passing I might add that it is the exception rather than the rule to find any mechanical devices at our water terminals in other localities.

The low coal rates on the Mississippi and the Ohio rivers are largely due to the very cheap type of barges used, which are taken down with the current in charge of a tow-boat, the chief function of which is to guide the tow rather than to furnish the motive power for hauling the load.

It has not been my good fortune to have seen an analysis of these very low freight costs, but they doubtless contain the elements of interest on investment, insurance, maintenance, and administration expenses; but probably, as the lines are owned by the great steel corporation using the ore, they are free from that iniquitous basis of charge of "what the traffic will bear," and may reasonably represent a fair cost of the service.

Let me invite your attention for a moment to this matter of freight rates, which is one of such prime importance to the industrial life of New England, where practically every item of raw material and every pound of finished product pays tribute to the great transportation companies handling them for you. The

admirable report of the Fuel Committee of the Boston Chamber of Commerce states that New England paid approximately $100 000 000 for the single item of coal during the calendar year of 1908, the value of which at the mines was about $30 000 000, leaving a charge of $70 000 000 for its distribution. Is not this a sum the proper disbursement of which is worthy of the most careful consideration and demands an intelligent investigation of any means which can reasonably promise a reduction of the enormous outlay? Let us see for a moment how the principal of charging what the traffic will bear works in this case. The all-rail rate from the Pittsburg district to Worcester, Mass., on coal, about a year ago, and it has probably not materially changed since, was $3.10 (I take the liberty of giving you again the figures of the Fuel Committee report, which may be familiar to you but are of such import as to bear repetition many times). The tide-water rate is figured as follows:

Pittsburg to Philadelphia,	$1.65
Philadelphia to Providence,	.50
Transfer to cars and weighing,	.21
Providence to Worcester,	.85
Total,	$3.21

Eleven cents greater than the all-rail rate.

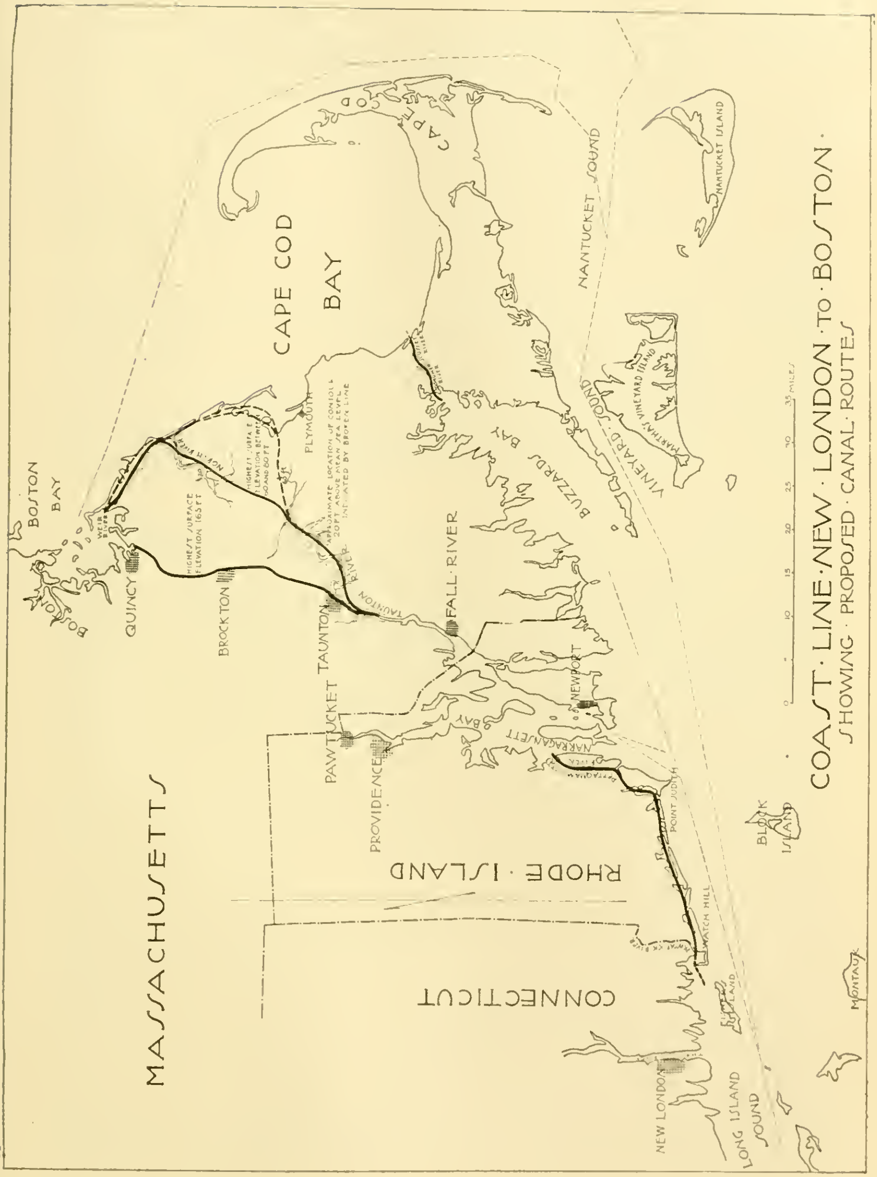
The distance from Pittsburg to Philadelphia is about 354 miles, giving a ton-mile rate of 4.7 mills; from Philadelphia to Providence by water is about 390 miles, giving a similar rate of 1.3 mills; and for the haul of 44 miles from Providence to Worcester a rate of 19.1 mills, or very close to 2 cents per mile, and this too after a charge of 21 cents for the transfer from the boat to the cars and weighing.

The all-rail distance from Pittsburg to Worcester is about 635 miles by way of Jersey City, which would give a ton-mile rate of 4.9 mills. This does not vary greatly from the rate from Pittsburg to Philadelphia, but you will observe is about one fourth the rate from Providence to Worcester, which would seem excessive even after making due allowance for the short haul of the latter. In fact, it appears that the rates are so arranged that the tide-water and all-rail rates meet about 50 miles from the coast. In

other words, any advantage to be derived from water transportation, which in the particular case we have been considering bears the ratio to all-rail transportation of 1.3 to 4.9, is to be confined to a narrow strip not exceeding 50 miles in width, bordering on the lines of waterways.

This disadvantage of distance from a water port is illustrated in another form which appears to me to involve great injustice although legally sanctioned by the Interstate Commerce Commission, and that is, permitting lower rail rates to points where tide water competition is encountered. Thus the rate to Taunton on lumber, I am informed, is $1.00 per ton more than it is to Fall River and New Bedford, although the lumber for the latter points is hauled through Taunton, which is either paying part of the Fall River and New Bedford bill as a penalty for not having established itself on the sea or is paying an entirely unnecessary tribute to the railroad company. Cotton, which is one of the great imports of New England and is rated as fourth-class freight, pays 10 cents per hundred from New York to Fall River or Providence, — within 2 cents of rates I have recently seen quoted from Baltimore to Liverpool. But the New England rate situation is well known to you all, and my reason for touching upon it here is that it may be fresh in your minds during this period of consideration of the projects that are being promoted by the Atlantic Deeper Waterway Association, which in general terms provide for a protected waterway along the Atlantic coast from Boston to Florida; that is, protected from the dangers of ocean navigation, thereby affording an available route for a cheaper type of carrier and in some cases saving very great distances between the points reached.

In outline the main project contemplates a canal connecting Boston Harbor with Narragansett Bay by way of the Taunton River and Mt. Hope Bay; thence across Narragansett Bay to Bissels Cove, a few miles below Wickford, R. I.; thence across a short divide into the valley of the Pettaquamscott River, south to a point back of Narragansett Pier. A curious feature of this stretch is found in the fact that although the valley is between two ranges of high, rocky hills, there is ample water in the river for navigation purposes in the upper two miles, reaching to a depth of 60 ft. Back of Narragansett Pier the line of the canal crosses


COAST · LINE · NEW · LONDON · TO · BOSTON ·
SHOWING · PROPOSED · CANAL · ROUTES
MASSACHUSETTS
RHODE · ISLAND
CONNECTICUT
CAPE COD BAY
BOSTON BAY
BOSTON
QUINCY
BROCKTON
TAUNTON
TAUNTON RIVER
FALL · RIVER
PAWTUCKET
PROVIDENCE
NEWPORT
NARRAGANSETT BAY
POINT JUDITH
WATCH HILL
BLOCK ISLAND
NEW LONDON
LONG ISLAND SOUND
MONTAUK
PLYMOUTH
BUZZARDS BAY
CAPE COD
VINEYARD SOUND
MARTHAS VINEYARD ISLAND
NANTUCKET SOUND
NANTUCKET ISLAND
HIGHEST SURFACE ELEVATION 165 FT
0 5 10 15 20 25 30 35 MILES

another short divide and enters the head of Point Judith Pond, through which it passes south to a connection with a series of ponds extending westerly along the southern shore of Rhode Island from Point Judith nearly to Watch Hill. (This section comes nearer to fulfilling the description of "within a biscuit's throw of the ocean" than any of the others north of Beaufort, N. C.) From Watch Hill the line passes into Little Narragansett Bay; thence into Fisher's Island Sound and Long Island Sound at about New London. The Sound is followed to New York; from there the canal will be carried across New Jersey and enter the Delaware River somewhere near Trenton, descend the Delaware, passing Philadelphia, Chester, Wilmington, Del., to Delaware City; thence across the state of Delaware into Chesapeake Bay; thence to Norfolk, Va., where it enters the land and crosses to the North Carolina sounds back of Cape Hatteras, to Beaufort, N. C. South of Beaufort it extends along the coast line through rivers, ponds, and lagoons to Florida.

The whole route might be divided into three divisions, that south of Norfolk being the lumber and agricultural division; between Norfolk and New York the coal division, constituting the entire water frontage of the great coal states; and from New York to Boston, the marketing division for the natural products of the other two.

It is not alone as a regulator of rates that this canal is designed to afford the cheapest means of transportation, but it serves to afford an indispensable supplement to the railroads traversing the Atlantic coast section and other portions of the country that can be reached. In 1907 the transportation facilities of the country were taxed to their limit and so far over-burdened that freight blockades were occurring everywhere. The products of industry could not be moved. At that time that great master of transportation, James J. Hill, said that it was the greatest problem the country had before it. He estimated that it would require the expenditure of $1 100 000 000 annually for five years to put the railroads in condition to properly handle the freight then offered, and that such a proposition could not be financed, nor could the labor be obtained to execute the work required; and I have seen it stated in the daily papers that he anticipates a recurrence of the trouble, and has increased the estimate previously made. A

slight idea of the work involved might be gained by consideration of the work of the Pennsylvania Railroad Company Terminal in New York, which has been in progress some four or five years and involves an expenditure of something like $100 000 000. Mr. Hill's estimate calls for 55 similar operations annually. The railroads are utterly unable to handle the freight when the rush comes, and are restricted more by lack of terminals than lack of trackage. Mr. Hill stated, in regard to the difficulties of 1907:

"A common carrier has reached its limit when it is moving, at all times, over its system as many cars as can run upon its tracks with safety, and be transferred and dispatched from its terminals and junction points without unreasonable delay. Beyond a certain limit, the increase of business cannot be handled by increase of cars and engines. . . . No additions of equipment and no increase of efficiency of operation can take the place of the imperatively required new trackage and terminal facilities."

President Roosevelt, in appointing an Inland Waterway Commission, said, in 1907:

"It is common knowledge that the railroads of the United States are no longer able to move crops and manufactures rapidly enough to secure the prompt transaction of the business of the nation, and there is small prospect of immediate relief. . . . There appears to be one complete remedy, — the development of a complementary system of transportation by water."

The Hon. C. P. Goodyear, of Brunswick, Ga., a close student of the conditions attendant upon the freight blockade of 1907, said:

"I want to give reasons which seem to me controlling, why, in the future development of the country, reliance cannot be placed even in the increase of 2 per cent. hereafter in railroad mileage. The greatest average yearly increase in railway construction between 1880 and 1890 of 7 300 miles per year, with a population ranging from 50 000 000 to 63 000 000, is followed by a period from 1890 to 1907 with but 3 400 miles average increased mileage per year, with a population ranging from 63 000 000 to 86 000 000. . . . The reduced mileage per year in the later period is due to increased cost of railway construction, not so much on account of increased cost of material and equipment, motive power, and labor as because of the rapidly increasing cost of right of way, of terminals and station locations in towns and cities.

"With returning prosperity, which is sure to come in increased volume with growing population, the railroads will indeed be utterly inadequate to handle traffic, and, without a supplementary system of transportation, agriculture, mining, and industrial growth must be curtailed."

It is plainly the lesson of experience that the railroads are not able to handle the products of our industry in times of prosperity, and it is a clear duty, if we would continue to expand in our industrial growth, to prepare as rapidly as possible for future requirements in this line; and it is my aim to urge this upon your attention to the end that the popular recognition of the importance of the subject will compel action. Congress has recognized the importance of the subject to the extent of providing surveys for the various routes and directing the preparation of the estimate of cost, which work now is about completed. It is generally believed by those who have given the subject consideration that all of these waterways should be owned by the national government, and thereby preserve for the people a water highway free for the use of all who desire. While this view may be to some extent inspired by the tendency of the great transportation companies to monopolize the business, it must not be forgotten that these great concerns, with all their trained machinery for securing the freight, will be forced to make use of the waterways for themselves on account of the conditions which will be available, but they cannot have an exclusive right of way, which will always be available for the small concern as well as the large corporation. The result in either case will be a lowering of rates.

With regard to the importance of this great movement to New England, it is desirable to consider its situation with respect to the rest of the country. It is farther from the points of production of all the raw material which enters into the products of its mills than any other manufacturing section of the United States, and hence is more deeply interested in the cheapest possible form of transportation that can be devised, both for the raw material and marketing its product. The manufacturing industries have attained a strong position in the industrial world, based on a thorough development of the available water powers and upon the characteristic energy, intelligence, and enterprise of its citizens;

but the extent of the industries has far outgrown the power of the watersheds, and the lesson of careful management and operation has been learned by her rivals and is being more and more effectively applied in other localities with the enthusiasm which always accompanies successful development of new lines of work, so that the difference of the cost of the finished product is measured more nearly to-day than formerly by the distance between the points of production and consumption of the raw materials. As those elements of cost dependent upon mental qualifications and the results of long experience become equalized in the different sections of the country, transportation becomes more and more the ruling factor in the strife for industrial supremacy. Under existing conditions New England is seriously handicapped in matters of cheap water transportation by the difficulties and dangers of the passage around Cape Cod and Point Judith, together with the stretch of ocean navigation from Race Rock at the eastern end of Long Island Sound to the western entrance of Vineyard Sound.

In the course of the traditional repetition of history this great movement in the United States, looking towards the development of waterways both natural and artificial, to the end that better facilities may be afforded, has revived.

Before the advent of the railroad era and after the highways had reached their economical capacity, attention was turned towards transportation by canal, and between 1783 and the end of the eighteenth century charters were issued for companies which should construct the Dismal Swamp Canal southward from Norfolk, Va.; the Chesapeake and Delaware Canal, joining the waters of those bays; and the Delaware and Raritan Canal, leading to New York Harbor, thus giving a waterway from the North Carolina sounds to Long Island Sound, which, however, from the modern point of view was of very small capacity. In April, 1808, Albert Gallatin, Jefferson's Secretary of the Treasury, in response to a resolution of Congress, presented a comprehensive plan involving a continuous inland waterway along the Atlantic coast. The present movement is, therefore, but a revival of the projects then proposed and in part carried out, enlarged and adapted to present-day needs.

It was a part of the Gallatin plan that tributary small canals threading the interior should bring freight to the main waterway

along the coast. Among others, a number of small canals were built from the coal regions of Pennsylvania to tide water, and until they became the property of the railroads served a useful purpose; but they carry little if any coal to-day. Consider for a moment what it would mean to New England could those canals be rehabilitated and adapted to modern requirements, so that a barge could be loaded at the mines and be brought to your New England ports without a transfer. Consider what it would mean to the states of Connecticut, central Massachusetts, Vermont, and New Hampshire, to have an adequate waterway extending from Long Island Sound up the valley of the Connecticut River, even if its benefits were limited to a strip 50 miles wide on either side. Would there not be enormous possibilities in a protected waterway leading from New England ports by way of the Hudson River, the new barge canal across New York State and the Champlain canal to the Great Lakes and the valley of the St. Lawrence, bringing you into touch with millions of population, consumers of your products, upon which freight of about one mill per ton mile would be paid instead of about five mills, the average railroad rate of the present day? The time consumed in the deliveries of freight by the water route would be much shortened. The average rate of progress of a freight car is but twenty-five miles per day. A week is no unusual time to elapse between the shipment and delivery of freight by rail between Boston and New York. I am told that three or four days is common between Philadelphia and Baltimore. I have had personal experience of an interval of three months between Jersey City and Salt Lake City. Once on board a barge and started in the tow, there is no sidetracking or delay, but a steady pushing forward, at a slow rate perhaps, to destination.

It is not expected that an intra-coastal canal is going to do away with coastwise ocean traffic, for the steamers built for the trade will continue to ply up and down the coast, and the sailing vessels to beat along their old-time tracks; but bulky freight, such as coal, lumber, cotton, and many commodities destined for inland points, will be carried by suitable vessels by water. And one essential element of the success of this entire project consists in the development of the most efficient type of boat adapted to the minimum depths of water in the various branches of the canals

in the entire system or such portions of it as they are ever likely to use.

Due to the necessity of building the ocean vessel of sufficient strength to resist violent storms, her cost in the United States is about \$71 per ton of freight carried. On the Great Lakes, vessels are subject to storms of less violence and the cost is about \$41.50. A Mississippi steamboat and 10 barges capable of transporting 10 000 tons of freight on $8\frac{1}{2}$ ft. of water can be built for about \$12.50 per ton of freight carried. The modern sea-going tow of steel barges with their ocean-going tug, costing about \$28 per ton, can be replaced on this proposed protected waterway by a type costing \$17 per ton, and by it Providence is brought 140 miles nearer Philadelphia and 250 miles nearer Baltimore. With a rate of 75 cents per ton from Philadelphia to Providence by sea, — about the highest rate usually paid, — it is found that the same return on the capital investment will be yielded with a rate of 48.6 cents by a canal aside from any saving due to the elimination of the dangers of the ocean trip.

The feature of the efficient adaptation of the type of vessel to the traffic is strikingly exhibited in the lake traffic, where this system is highly developed, when last year the largest traffic was conducted with 20 per cent. of the tonnage out of commission, owing to improvements in handling freight (10 000 tons of ore loaded in thirty minutes, four to five hours in unloading).

To-day the eastern New England states cannot be reached by water without at least a short ocean trip. Upwards of 20 000 000 tons of freight pass the southern shore of Rhode Island annually, some coming around the eastern end of Long Island, but the great bulk coming out of Long Island Sound.

With the fall and winter storms comes the annual tale of disaster, especially to the towing fleet, and every year records the loss of a number of barges too often accompanied by loss of life; the sailing fleet is not exempt, and fog brings many a steamer with valuable cargo to the end of her career. With regard to the barges, the almost universal criticism is, " Why should the government permit the use of such vessels for an outside trip? " Regulations have been established by Congress looking to an amelioration of these conditions which went into effect January 1, 1909;

but with each additional restriction there is additional expense which is adding to the cost of your transportation. The inexpensive type of barge, called sometimes the "coffin barge," but more properly, I believe, the "box barge," now growing in use for the transportation of coal from New York to Narragansett Bay points, is a boon to that section but too light to come to Boston unless there should be a protected way. As it is now, they are frequently detained for periods of two weeks at New London awaiting a chance to get into Narragansett Bay. A short time ago I saw one that had taken thirty days to make the voyage from New York to Pawtucket.

The stretch of ocean navigation from Race Rock at the eastern end of Long Island Sound to the western entrance to Vineyard Sound, about sixty miles in length, is perhaps the scene of more marine disasters accompanied by serious loss of life and property than any like distance along the Atlantic coast, save that from Nantucket Sound to Provincetown. And this condition pertains not by reason of more severe storms and heavier fogs than elsewhere, although there is an abundance of both, but largely from the enormous traffic passing. This traffic is in a way congested, for in thick or foggy weather every vessel bound for Narragansett Bay is obliged to take her departure from Race Rock Light and run her prescribed course for a certain number of hours and minutes and find the Point Judith whistling buoy or she is in imminent danger; and the vessel bound out of the bay is obliged to take the same line from the whistling buoy for Race Rock. In the same way vessels bound to and from points east of Narragansett Bay are compelled to follow prescribed courses to find their turning points, and the two courses are quite close together. At the same time the sailing vessels, forming about 28 per cent. of the whole fleet, are beating across these courses in adverse winds. In addition to the Sound fleet there are those coming from southern ports around Montauk Point and to the eastward of Block Island, all converging on the Point Judith buoy and the Vineyard Sound Light Vessel, increasing the hazard of the navigation of these waters.

It is not alone the barges of light construction that meet with disaster, but the parting of hawsers of the large barges from the

Chesapeake and Delaware bays is of frequent occurrence. Under such circumstances, the barge adrift is either picked up, goes ashore, founders, or works out to sea and weathers the gale; the whole, even under the most favorable conditions, a serious, costly, and hazardous experience. As the route extends eastward, the Nantucket and Monomoy shoals are encountered and the dangers vastly increased.

A map prepared in the United States Engineer Office at Newport, a few years ago, gives the approximate location of 1 016 marine disasters which had occurred between Fisher's Island at the eastern end of Long Island Sound and Provincetown, from 1880 to 1903, and there were doubtless many others of which no record was available. Of the total number, 377, or 35 per cent., occurred west of Narragansett Bay, such is the index of the dangers attendant upon that short ocean voyage from Race Rock to Narragansett Bay, and, taken in connection with the frequent long detentions of whole tows of barges at New London for weeks at a time, awaiting a chance to round Point Judith, offers a strong reason for building that section of the Rhode Island canal within a biscuit's throw of the ocean.

Estimated Cost of Sea-Level Canal between Narragansett Bay and Long Island Sound.

Description.	Cost.
Canal 18 ft. depth of water, 125 ft. bottom width:	
Cost of construction	$11 945 000
Cost of annual maintenance, capitalized at 4 per cent	3 750 000
Total cost	$15 695 000
Canal 25 ft. depth of water, 200 ft. bottom width:	
Cost of construction	$24 370 000
Cost of annual maintenance, capitalized at 4 per cent	4 000 000
Total cost	$28 370 000

Note. — The 18-ft. canal would have a bottom width of 250 ft. in the approaches and in the ponds traversed; the 25-ft. canal would have a bottom width of 300 ft. in the approaches and in the ponds traversed.

Estimated Cost of Various Types and Dimensions of Canals between Narragansett Bay and Boston.

Description.	Depth of Water. 18 Ft.	25 Ft.
Lock canal, 35-ft. summit, bottom width 200 ft.:		
Cost of construction, Taunton River to Hingham Harbor	$29 590 000	$40 047 000
Cost of annual maintenance, capitalized at 4 per cent	20 178 000	20 903 000
Total cost	$49 768 000	$60 950 000
Lock canal, 35-ft. summit, bottom width 125 ft.:		
Cost of construction, Taunton River to Hingham Harbor	$24 955 000	$32 470 000
Cost of annual maintenance, capitalized at 4 per cent	20 178 000	20 903 000
Total cost	$45 133 000	$53 373 000
Lock canal, 20-ft. summit, bottom width 200 ft.:		
Cost of construction, Taunton River to Plymouth Harbor	$20 570 000	$26 848 000
Cost of annual maintenance capitalized at 4 per cent	14 035 000	14 785 000
Total cost	$34 605 000	$41 633 000
Lock canal, 20-ft. summit, bottom width 125 ft.:		
Cost of construction, Taunton River to Plymouth Harbor	$17 453 000	$21 678 000
Cost of annual maintenance, capitalized at 4 per cent	14 035 000	14 785 000
Total cost	$31,488 000	$36 463 000
Sea-level canal, bottom width 200 ft.:		
Cost of construction, Taunton River to Plymouth Harbor	$35 696 000	$47 133 000
Cost of annual maintenance, capitalized at 4 per cent	11 035 000	11 835 000
Total cost	$46 731 000	$58 968 000

Sea-level canal, bottom width 125 ft.:

Cost of construction, Taunton River to Plymouth Harbor	$28 429 000	$37 420 000
Cost of annual maintenance, capitalized at 4 per cent	11 035 000	11 835 000
Total cost	$39 464 000	$49 255 000

NOTE. — All river and harbor sections to have a bottom width of 300 ft.

DISCUSSION.

MR. T. G. HAZARD, JR. I would like to ask if it will be possible to keep the canal open during the ice season.

MR. PARRISH. That has been considered a good deal, and it is generally thought that the canal can be kept open at such times as the rivers are open; that is, that there would be no more likelihood of the canals freezing up than there would be, for instance, of the Providence River or Pawtucket River, although there might be a little delay on that account. But the facilities for getting through and running on schedule time, not having to wait on account of storms or fog, would enable the merchants during the fall months to stock up with coal before the winter season came on. There is very great detention now even in the short trip from Long Island Sound into Narragansett Bay, and that is vastly increased, of course, in the trip from Long Island Sound to Boston.

MR. FRANK L. FULLER. How would the lock canals be supplied with water?

MR. PARRISH. They would have to be supplied, I think, by pumping. I have not seen any of the details of the lock canals. The Rhode Island canal would be purely a sea-level canal. The state made a survey down through Brockton for a canal at one time, and it was proposed to pump from the sea level up, to supply the water in that way.

MR. FULLER. Wouldn't that be very expensive?

MR. PARRISH. Yes; I think probably it would be.

MR. A. S. NEGUS. I have been in the towing business a lot around Cape Cod, and also in Long Island Sound, and I have often thought that an inside passage, such as has been suggested, would

be of very great advantage. As the gentleman has said, there are a great many serious delays from storms and bad weather, particularly from the Little Gull down to the end of Cape Cod. It is very dangerous both for boats and for the barges. The barges always suffer, of course, the most. Oftentimes in bad weather it is very serious for them, and also for sailing vessels. I have been shipwrecked twice on Nantucket Shoals with tows, and if we had had the Pawtucket Canal or this other canal which has been described, it would have been a wonderful advantage, both in respect to time and safety. When these long tows pass down through outside, they are a danger to everything, and anything of the kind which is suggested I think would be of very great help.

PROTECTION OF NEW YORK'S WATER SUPPLY FROM POLLUTION DURING CONSTRUCTION WORK.

BY ANDREW J. PROVOST, JR., SANITARY EXPERT, BOARD OF WATER SUPPLY.

[*Read September 13, 1911.*]

The existing water supply for the boroughs of Manhattan and Bronx in the city of New York is furnished from reservoirs and lakes in the watersheds of the Croton, Bronx, and Byram rivers in the counties of Westchester, Putnam, and Dutchess, on the east side of the Hudson River. The aggregate supply drawn from these sources approximates 300 million gallons per day.

The additional supply of 500 million gallons per day, work for which is now advanced, is to be taken from the watersheds of the Esopus, Rondout, Schoharie, and Catskill creeks in the counties of Sullivan, Ulster, Greene, Schoharie, and Albany, on the west side of the Hudson. This is generally referred to as the "Catskill supply."

The work now being undertaken includes the construction of the Ashokan Reservoir, an impounding reservoir of about 127 thousand million gallons, located in the foothills of the Catskill Mountains back of the city of Kingston; the Kensico Reservoir, an equalizing reservoir of about 40 thousand million gallons capacity, formed by combining and enlarging the existing Kensico Reservoir and Rye Pond storage basins near Valhalla in Westchester County; the Hill View Reservoir, a distributing reservoir of about 900 million gallons, near Yonkers, just north of the New York City line; the Catskill aqueduct, a conduit about 92 miles in length between the Ashokan and Hill View reservoirs, with a depressed crossing under the Hudson River at Cornwall; and the distributing aqueduct, a conduit of about 27 miles in length, from Hill View Reservoir through Manhattan Island to Brooklyn and under the Narrows to its terminus at Silver Lake on Staten Island, with branch conduits in the boroughs of Brooklyn and Queens.

The estimated cost of the entire work, including development of the Rondout, Schoharie, and Catskill watersheds and the installation of the filtration plant not yet undertaken, is \$162 000 000.

These constructions, involving the employment of many thousand alien laborers, presented sociological and sanitary problems that required careful consideration and study, particularly where the site of the works occupies watersheds of important potable supplies.

Early in its work the Board of Water Supply realized the importance of these matters and undertook their careful study.

In the first place, the communities through which the work passed required protection against infection by contagious and communicable diseases.

Second, the operations of the work being within or adjacent to numerous watersheds contributing surface water for public and private supplies, the reasonable protection of these supplies against pollution was imperative.

Finally, in order that the work might proceed effectively and without interruption, and for humanitarian reasons, it was essential that the health of the force be maintained and all possible preventable disease eliminated.

These questions on similar work have heretofore been largely overlooked or left to the discretion of local boards of health, which, as a rule, have not been active until unsanitary conditions became so acute as to attract attention by important outbreaks of disease.

Some attempt to control such conditions by legislative enactment has been made in Great Britain and elsewhere, but the board having control of the Catskill supply undertook to draft into the specifications of construction contracts conditions regulating sanitary conduct on the part of the contractors' employees, and they have endeavored to secure the observance of these by systematic inspection.

No similar specifications were available for use as a basis of action, and those which have been adopted on this work for the protection of the Croton supply, whose watershed is occupied by the new aqueduct for a distance of about twelve miles, are here quoted in part for purposes of general interest.

For works occupying less important watersheds other specifications somewhat less forceful have been drafted, and where the works are outside of watersheds the specifications are still more moderate.

The following requirements have been embodied in the specifications for constructing the aqueduct in the four principal contracts occupying the Croton shed where the work crosses Croton Lake and several of the tributary streams.

SANITARY PRECAUTIONS.

(Article XXXII.)

Sanitary Precautions.

Section 50. The contractor and his employees shall prevent nuisances in and about all camps and works; shall protect water courses, reservoirs, wells, and other sources of water supply, public or private, from pollution, contamination, or interference, and safeguard the public health, as may be directed from time to time by the constituted authorities of the state and city. The contractor shall summarily dismiss and shall not again engage, except with the written consent of the engineer, any employee who violates this section.

Inspection by Engineer. Sanitary Precautions to be Satisfactory. Compliance with Sanitary Regulations.

Section 51. The engineer shall have the right, in order to determine whether the requirements of this contract as to sanitary matters are being complied with, to enter and inspect any camp or building or any part of the works, and to cause any employees to be examined physically or medically or to be vaccinated or otherwise treated; also to inspect the drinking water and food supplied to the employees. The sanitary precautions, the care of the employees, the camps and all territory occupied by the contractor, shall at all times be satisfactory to the engineer. The contractor shall promptly and fully, and in every particular, comply with all orders and regulations in regard to these matters, including all sanitary and medical rules and regulations which may have been or may be promulgated from time to time. And to this end and to properly preserve the peace, the Board of Water Supply police shall have the right of access to the contractor's camps and quarters.

Quarters and Stables.

Section 52. The contractor shall provide suitable and satisfactory buildings for the housing, feeding, and sanitary necessities of the men, and suitable stabling for the animals employed upon the work. All buildings for these or kindred purposes shall be built only in accordance with approved drawings and specifications. All houses occupied by employees shall be thoroughly screened to exclude mosquitoes and flies. The quarters for the men shall be grouped in properly arranged camps. The contractor shall submit the locations proposed for his camps and buildings to the engineer for approval, and no buildings shall be erected until such approval shall have been obtained. Camps shall, if ordered, be enclosed by barbed wire or other approved fences not less than ten (10) feet high, with not more than two (2) entrances. Each camp and the grounds surrounding it in all directions shall be thoroughly illuminated by electric arc lamps or other acceptable lights. This illumination shall be maintained from sundown to sunrise every night during the occupation of the camp, unless otherwise ordered. Employees may, so far as practicable, be required to remain within camp when not at work.

Sanitary Conveniences and Disposal of Excreta. Attendants. Preventing Nuisances.

Section 53. Buildings for the sanitary necessities of all persons employed on the work, beginning with the first men employed to build camps or for other preliminary operations, shall be constructed and maintained by the contractor in the number, manner, and places ordered. All persons connected with the works shall be obliged to use these conveniences under penalty of discharge. Unless otherwise directed, the sanitaries shall be provided with water-tight removable receptables of suitable capacity. These receptacles, if used, shall not be allowed to overflow, but shall be removed, without spilling, at required intervals, their contents at once treated as directed, and then promptly taken to a designated place outside the watershed, and there disposed of as ordered. If incinerators be used, they shall be efficiently operated. The contractor shall provide a sufficient number of acceptable attendants to keep all sanitaries in satisfactory condition and compel employees to use them. The contractor shall rigorously prohibit the committing of nuisances within the tunnels, the aqueduct, or other completed or partially completed structure, or upon the land of the city about the works, or upon adjacent private property.

Medical and Surgical Attendance. Hospitals.

Section 54. The contractor shall retain the services of acceptable qualified medical and surgical practitioners, to the number ordered, who shall have the care of his employees, shall inspect their dwellings, the stables, and the sanitaries as often as required, and shall supply medical attendance and medicines to the employees whenever needed. The contractor shall provide, from approved plans, one or more buildings, properly fitted for the purposes of a hospital, with facilities for heating and ventilating in cold weather, and for screening and ventilating in warm weather. These hospitals shall have an ample number of beds to properly care for sick or injured employees, and shall be provided with all articles necessary for giving "first aid to the injured," as well as with all necessary medicines and medical appliances for the proper care for the sick and injured. Another building of approved design shall be provided and equipped as an isolation hospital, and any employee who shall be found to have a communicable disease shall be at once removed from the camp to this hospital, and there isolated and treated as directed. Whenever practicable, an employee having a communicable disease shall be removed, when and as directed, to a hospital outside the watershed.

Medical Supervision of Employees.

Section 55. The medical supervision of the contractor over his employees shall extend to the physical and medical examination of all applicants for employment, in order to prevent persons having communicable diseases from becoming connected with the work, and the contractor shall employ only persons shown by such examination to be free from communicable diseases. Whenever, in the opinion of the engineer, it is necessary for the protection of the public health or the health of the employees, the contractor shall remove any employee from the work either to a hospital at or near the works or to a more remote hospital, or shall remove permanently from the work or any camp any employee whose presence is believed to endanger the health of other persons.

Health Reports.

Section 56. Once each week, or more frequently if required, the contractor shall give the engineer, in such detail as may be prescribed from time to time, a written report, signed by the physician in regular attendance, setting forth clearly the health conditions of the camp or camps and of the employees. If any

case of communicable disease be discovered, or any case of doubtful diagnosis, it shall be reported at once to the engineer, by telephone or messenger, and confirmed in writing.

Domestic Water-Supply. Bath and Laundry Facilities.

Section 57. The water furnished by the contractor shall include a sufficient supply of drinking water of acceptable quality for all his employees, to be obtained from approved sources. He shall provide ample bathing and clothes-washing facilities for his employees and sufficient water of acceptable quality therefor. If any water supply for domestic uses should become contaminated, the contractor shall promptly provide a new supply from an approved source and abandon the contaminated supply, or shall provide works for purifying the contaminated water when and as ordered.

Disposal of Wash Water and Stable Drainage.

Section 58. All wash water from kitchens, laundries, and other places, and all drainage from stables, shall be conveyed by satisfactory means to places directed, where such drainage shall be treated by the means ordered so as to yield an acceptably innocuous effluent.

Drainage from Camps and Tunnels to be Filtered.

Section 59. Drainage from camps and tunnels and from other places yielding water unfit for direct discharge into a reservoir or tributary thereof shall be conducted in tight drains or other approved conveyors to filters, septic tanks or other disposal plants of approved construction, at places designated, and treated as directed to produce an acceptable effluent. Such effluent shall be discharged only in the manner and at the place or places directed.

Garbage Disposal.

Section 60. Garbage, both liquid and solid, shall be promptly and satisfactorily removed from the buildings and immediately placed in approved tight receptacles of sufficient capacity for about one day's ordinary production. At least once in every twenty-four hours all such garbage shall be incinerated or otherwise thoroughly and satisfactorily disposed of in an approved manner.

Contractor to Build Sanitary Works.

Section 61. The contractor shall build, in accordance with drawings and directions furnished from time to time by the engineer, such disposal plants, sewers, drains, and other structures, and shall do such other work, not herein particularly specified, as may be ordered for carrying out the intent of the sanitary precautions of this contract.

The five labor camps established for these contracts have a maximum population of about 1 500. The sites are in all cases located on property leased by the contractors after most careful study in which consideration was given to exposure, drainage, accessibility to the work, including sanitary transportation of the men to and from the camps, and protection against pollution of the lake and streams from the camps themselves with available precautions. Some of these precautions are:

The prompt incineration of all human discharges.

The collection and treatment of all liquid camp wastes from kitchens, laundries, lavatories, etc.

The collection and treatment of all storm water falling within the camp areas.

The collection and prompt destruction of all garbage and stable manure.

The physical examination of all applicants for employment and their careful medical observation while in camp or on the work.

The prosecution and punishment of persons committing nuisances.

The enclosing of camp areas by man-proof fences.

The illumination of camp grounds.

General precautions for maintaining the health of the force by supplying adequate and suitable housings, supplies of pure drinking water, hospitals for treatment and isolation and constant medical attendance.

INCINERATION.

The incineration of human wastes has been accomplished usually in apparatus adopted by the United States Army since 1907 for

its encampments, in which the material is evaporated in a sheet-iron receptacle having from one to four seats. This process is effective, but in the hands of cheap labor, such as is usually employed, the record of absence from odors does not compare favorably with army practice. Moreover, the apparatus, being originally designed to be portable, is too light for continuous hard driving under ignorant or careless management. The charges for repairs and renewals have in some cases been so burdensome that modified furnaces have been designed and constructed by some of the contractors to overcome this objection. Experience on the whole has shown it is entirely feasible to properly and economically dispose of human wastes in this manner, and that the results outweigh complaints of odors which at times arise.

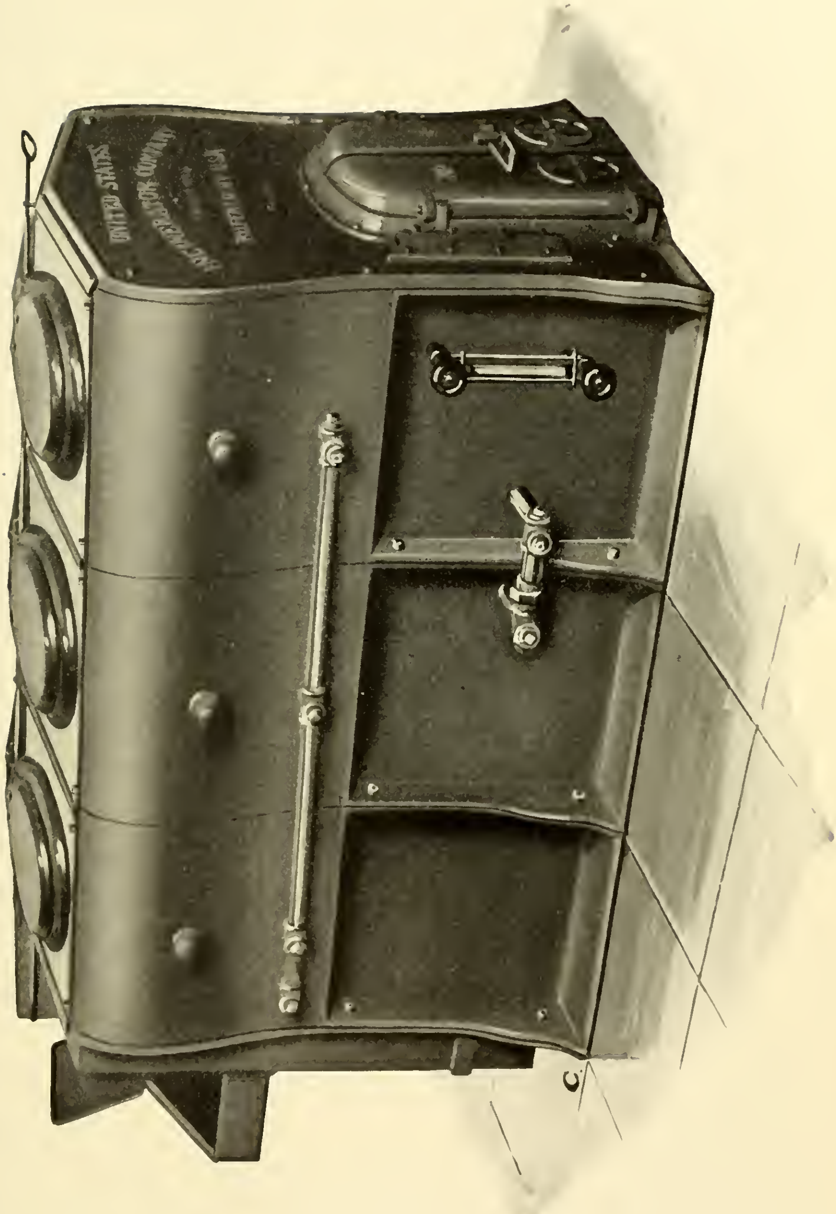
LIQUID CAMP WASTES.

Liquid camp wastes from plumbing fixtures, such as sinks, tubs, showers, lavatories, etc., are collected in a system of sewer pipes, passed through a grease trap and settling tank, thence through a sand filter and are finally treated with hypochlorite of calcium solution before being discharged into a water course.

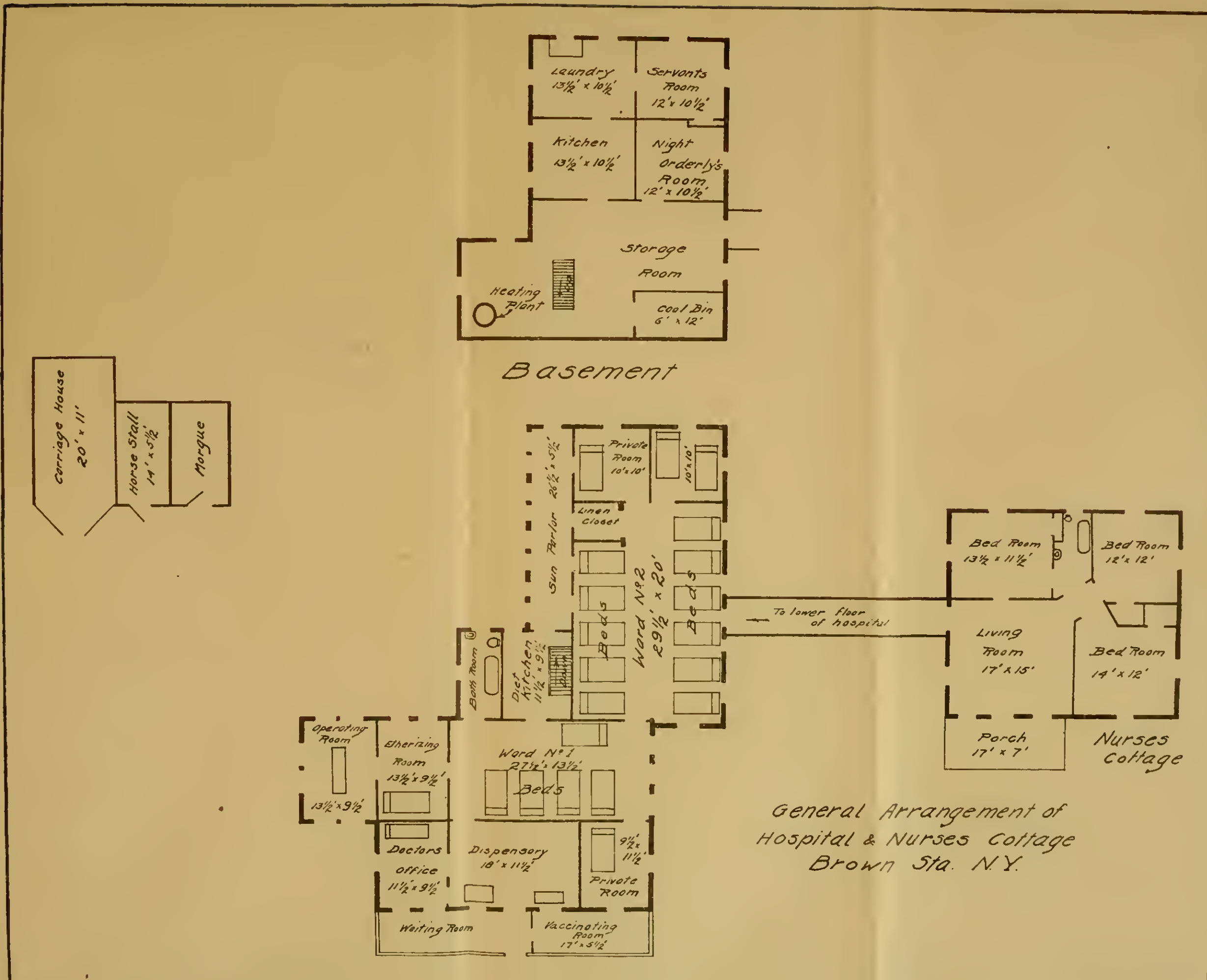
STORM WATER RUN-OFF.

All rain water falling outside of the man-proof fence is diverted by suitable ditches. That falling within is collected in open trenches and culverts and delivered to a sedimentation basin with earth banks and floor, having storage capacity for run-off proportional to the size of the camp. The outflow from these basins passes to two or more sand filter units designed to take $2\frac{1}{2}$ million gallons per acre per day without negative head. The capacity of the sedimentation basin, together with the designed rate of filtration, is as a rule about .8 of Talbot's curve for run-off from long heavy rainfalls. The filtrate is automatically treated with hypochlorite solution in proportion to the flow, and in some cases it is thereafter held for a short period in a timber retention basin before being permitted to enter a water course.

PLATE I.
N. E. W. W. ASSOCIATION,
SEPTEMBER, 1911.
PROVOST ON
PROTECTION OF NEW YORK'S WATER SUPPLY.



TYPICAL EVAPORATIVE FURNACE FOR INCINERATION OF HUMAN WASTES.



General Arrangement of
Hospital & Nurses Cottage
Brown Sta. N.Y.

GARBAGE AND MANURE.

Garbage is collected in approved covered cans and daily removed to a pit having a central masonry cone and there destroyed by combustion.

Stable manure is not permitted to accumulate but is collected daily and either burned or disposed of for fertilizing purposes.

MEDICAL.

Each camp has a medical officer always on call, whose duty it is to physically examine all applicants for work and to vaccinate all persons admitted to the camps and works. The certificate of vaccination issued by him to an applicant is good on all Board of Water Supply work for one year. The physician is also required to provide medicine for and to treat all camp inmates and laborers needing medical and surgical aid. Each camp hospital contains a dispensary, an operating room, a bath, a room for nurse or orderly, and a ward with beds for two per cent. of the force and 600 cu. ft. of space for each bed. There is also a small detention ward for temporary isolation and observation purposes. The entire building is steam heated and lighted by electricity. It is the physician's further duty to supervise all sanitary works and to enforce the observance of sanitary regulations. He is required to present a weekly health report, giving the camp population, the names and addresses of all employees residing out of camp (these include as a rule only the higher grades of labor), an itemized statement of surgical and medical cases, with transfers and deaths, the number of persons admitted to camp and works, the number admitted by vaccination or certificate, also the sanitary and health conditions of camp and employees at the date of the report.

The presence of the force of aqueduct police along the line of the work is of very great assistance in enforcing sanitary conduct and in effecting rigid isolation and quarantine when required.

CAMP BUILDINGS.

Previous to the construction of the camp the contractor is required to submit a layout plan indicating the number, character,

and arrangement of the buildings to be erected, together with detailed plans of all structures. These include dormitories, mess halls and kitchens, wash houses for laundry and lavatory purposes, hospitals for treatment and isolation, stables, sanitaries or toilet buildings, etc. All buildings are detached, having light on four sides and sufficiently close to produce a compact camp without crowding.

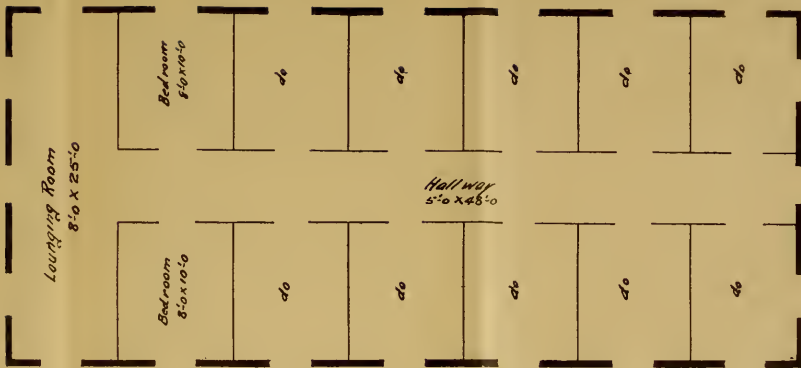
The dormitories are, as a rule, one-story structures with a central corridor extending the entire length thereof, with rooms for two or four men opening from it. One recreation or lounging room is usually provided in each building. The interior partitions are usually dwarfed, terminating at the plate line with wire netting or slats above this line to the roof, on the peak of which one or more louvered ventilators are placed, according to the length of the building. Each inmate is provided with a separate bed, bunk, or cot, and has 400 cu. ft. of space. The window area is about 3 sq. ft. per person, and the vent area is about $\frac{1}{3}$ sq. ft. per person. The buildings are heated by stoves or steam coils, and are usually lighted by electricity. The inmates are expected to keep their rooms clean, while a cleaning gang attends to the corridors and lounging rooms. No eating or storage of foods is permittted in the dormitory buildings. The mess halls and kitchens are in separate rooms, and are suitably ventilated and screened. Where bake ovens are provided for Italian labor, they are housed to give shelter and to facilitate cleaning.

The wash houses have concrete floors and are provided with laundry tubs, hand basins, and shower baths.

The treatment and surgical hospital has already been described. The isolation hospital is a simple building with ward space, 600 cu. ft. for one per cent. of the force, together with a kitchen and bed-room for nurse or orderly. This building is surrounded by a man-proof fence, for purposes of quarantine during sickness and convalescence.

The stables have concrete or other non-absorbent floors which are suitably drained. With respect to size and ventilation they are carefully designed and compare favorably with the other camp buildings.

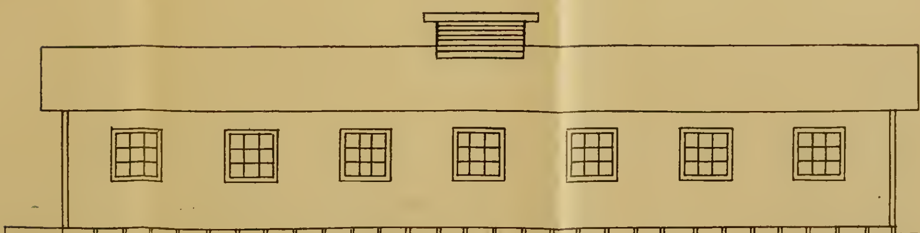
The sanitaries have concrete floors and screened window, door,



PLAN

WORKMANS DWELLING FOR 24 INMATES
CONTRACT 30
KEYSTONE STATE CONSTRUCTION CO.

SCALE OF FEET
0 5 10



SIDE ELEVATION

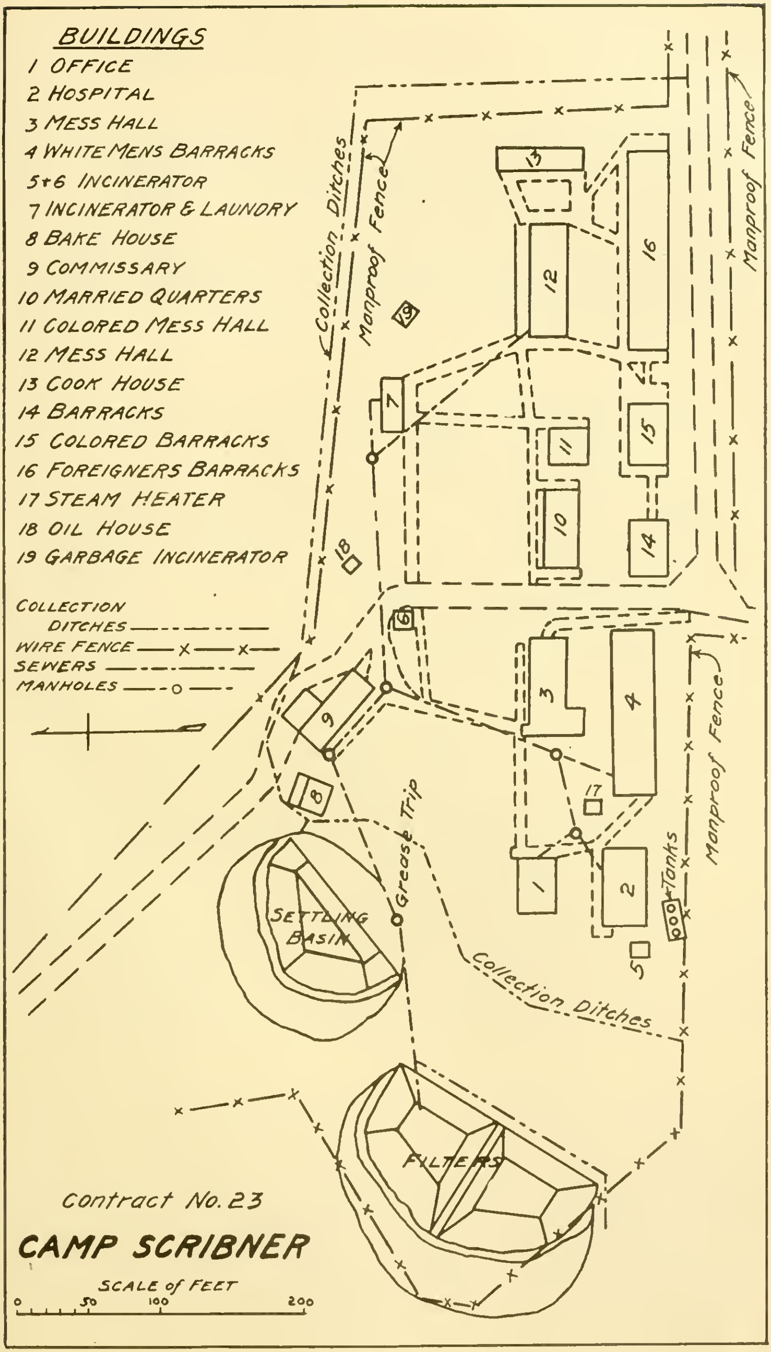

BUILDINGS
1 OFFICE
2 HOSPITAL
3 MESS HALL
4 WHITE MENS BARRACKS
5+6 INCINERATOR
7 INCINERATOR & LAUNDRY
8 BAKE HOUSE
9 COMMISSARY
10 MARRIED QUARTERS
11 COLORED MESS HALL
12 MESS HALL
13 COOK HOUSE
14 BARRACKS
15 COLORED BARRACKS
16 FOREIGNERS BARRACKS
17 STEAM HEATER
18 OIL HOUSE
19 GARBAGE INCINERATOR
COLLECTION DITCHES
WIRE FENCE
SEWERS
MANHOLES
Collection Ditches
Manproof Fence
Manproof Fence
Manproof Fence
Grease Trip
Tanks
Settling Basin
Collection Ditches
Filters
Contract No. 23
CAMP SCRIBNER
SCALE of FEET
0
50
100
200

Fig. 1.

and vent openings. The incinerators installed therein were all originally of the army type. In some instances these are now being superseded by removable water-tight receptacles which are frequently collected and emptied into an isolated furnace, in which a fire is kept constantly burning. When such receptacles are to be used, a preferable plan is that adopted on some of the more recent contracts, where the furnace is housed in the

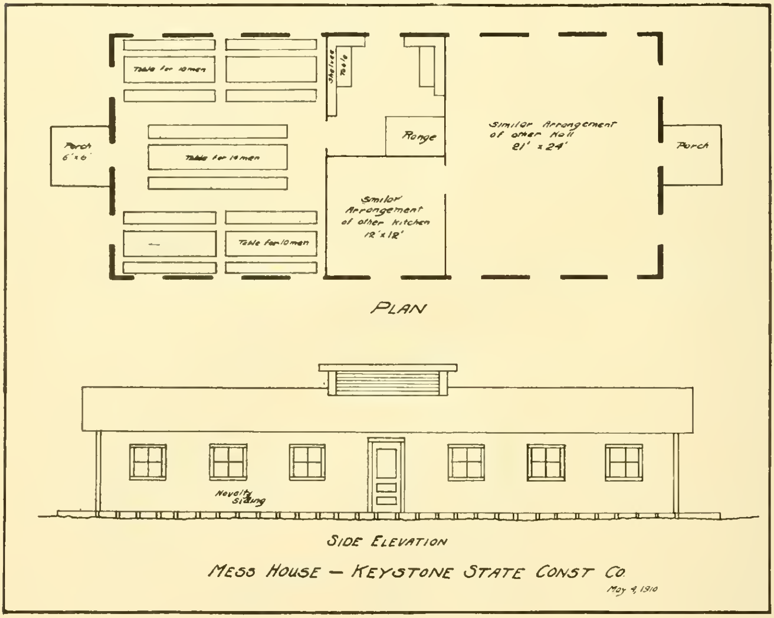


FIG. 2.

same building, thereby avoiding transporting the cans through the camp.

All of the buildings herein mentioned are timber structures with the floor beams raised above the ground level. The covering is of clapboards or rough sheathing covered with rubberoid or similar material.

Water supplies for camp purposes must be from sources approved

after careful analysis. It is provided under pressure from suitable storage tanks.

SPECIAL PRECAUTIONS.

Incinerator plants are located at shafts and portals and along the line of the works, or else portable water-tight receptacles are provided and brought into camp daily for incineration of contents.

Realizing that the undetected commission of nuisances is more likely to occur in the tunnels than above ground, all mine water as well as the rain wash from spoil banks is collected, filtered and treated with hypochlorite solution in proportion to the flow before allowed to enter the streams. In some cases it has been found more convenient to treat constantly the entire flow of the stream with hypochlorite solution.

Where it has been possible without too great inconvenience to locate a camp off the watershed, this precaution has been followed, as in the case of labor camp for Kensico Dam. In this contract the additional precaution was taken to prohibit so far as possible the use of animals where traction engines and machinery could be used. In connection with this contract, some fifty to sixty dwellings within or adjacent to the future flooded area have been destroyed after purchase by the city in order that their occupancy by undesirable tenants might be effectively prevented.

A system of laboratory diagnosis of important diseases has been provided whereby samples of sputum, membrane, blood, faeces, etc., may be promptly examined and effective means taken for controlling the disease. Where messages relating to these diseases are transmitted by telephone or telegraph, a prescribed code is used.

RESULTS.

During the year 1910 the average number of workmen and camp inmates occupying the Croton and Bronx watersheds was 2 365. The death-rate, exclusive of violent deaths, was 4.4 per 1 000. There were no cases of typhoid among the contractor's employees, and but one case among camp inmates. These records corre-

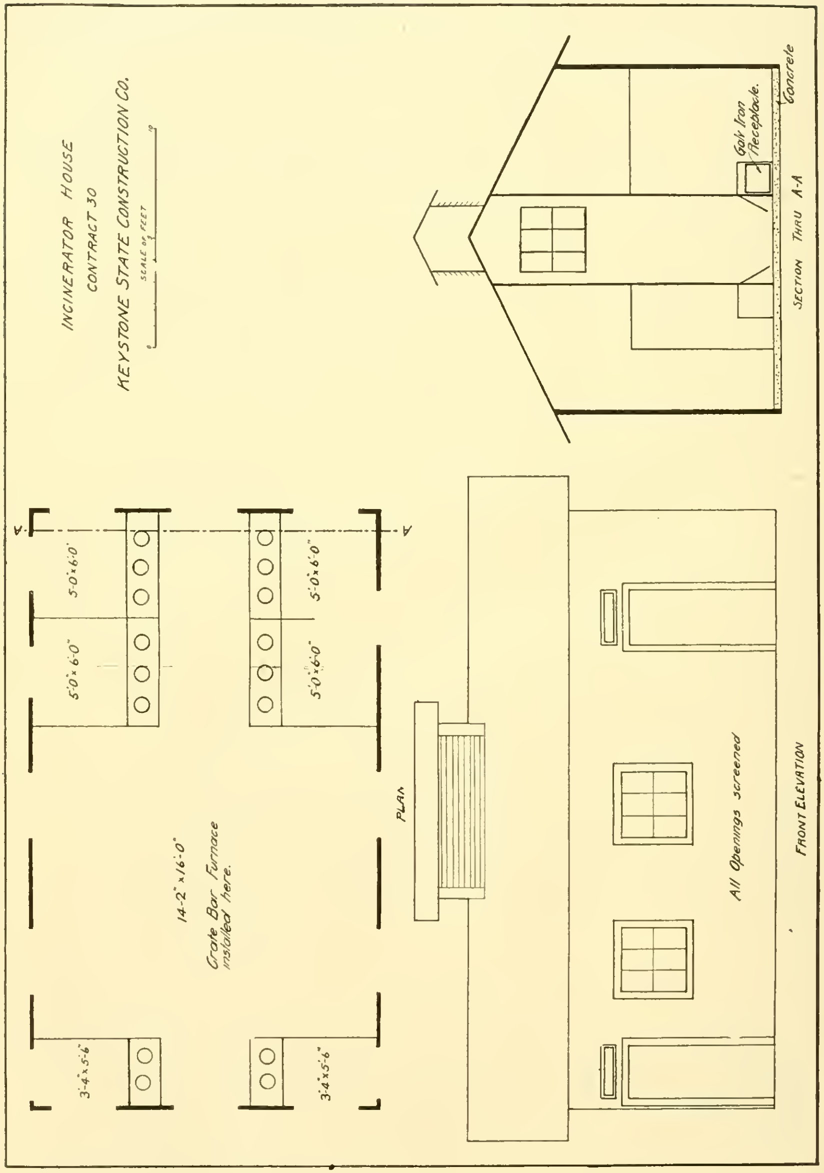

INCINERATOR HOUSE
CONTRACT 30
KEYSTONE STATE CONSTRUCTION CO.
SCALE OF FEET
5'-0"x6'-0"
5'-0"x6'-0"
5'-0"x6'-0"
5'-0"x6'-0"
14'-2"x16'-0"
Grate Bar Furnace installed here.
3'-4"x5'-6"
3'-4"x5'-6"
PLAN
Galv Iron Receptacle
Concrete
SECTION THRU A-A
All Openings screened
FRONT ELEVATION

FIG. 3.

spond substantially with statistical results from about 15 000 employees on the entire line of work.

The expense of carrying out this great plan of sanitation and preventive medicine has necessarily been large, and it is hoped the final results will fully justify the expenditure and effort. If such be the case, the future problems that engineers and contractors on large isolated construction work must consider will include similar precautions and observances. If it is worth what it costs, it must gradually become general practice, and in order that its application may not be unfair or burdensome, the contractor must be furnished, before presenting his bid, with definite and specific information regarding the nature and extent of the duties and obligations to be imposed on him.

Each enterprise will present its own peculiar conditions, and these will have to be carefully thought out in advance. The mere formulation of sanitary rules and regulations will ordinarily be entirely ineffective unless provision is made for their enforcement by painstaking inspection. Trained men of suitable temperament are required for this work.

The application of the essential features described in this paper are not confined to municipal or governmental contract work, but apply as readily to mining, lumber, railroad, and recreation camps, expositions, and military and religious encampments and other places where numerous people are required to be housed and maintained in temporary quarters. Previous history shows that wherever attempt has been made to congregate the habitations of more than a very limited number of human beings or animals, there results a natural tendency toward destruction of the colony by its own discharges and waste products. This tendency is largely controlled by the introduction of suitable sewerage under proper conditions, but where sewerage systems could not or have not been installed, as in temporary encampments, such as have been mentioned, history records in substantially all instances the general prevalence of fever and pestilence, diseases now considered unnecessary and preventable. Investigation made subsequent to the Spanish War showed that more than 90 per cent. of the United States volunteer regiments developed typhoid fever within eight weeks after going into camp, and that about one fifth of the soldiers

in the national encampments contracted typhoid fever, and that the mortality from this disease amounted to more than 86 per cent. of all the fatalities.

Within the past few years, however, it has been conclusively shown that these results are entirely unnecessary and that with suitable precaution temporary encampments can be maintained without prevalence of disease exceeding that of the best-regulated cities and towns.

THE HUDSON RIVER CROSSING OF THE CATSKILL AQUEDUCT.

BY ROBERT RIDGWAY, DEPARTMENT ENGINEER, BOARD OF WATER SUPPLY, CITY OF NEW YORK.

[*Read September 13, 1911.*]

It is generally known that the city of New York is going to the Catskill Mountains for an additional supply of water and that construction work on the project is well advanced towards completion. The source of this supply and the point of distribution being on opposite sides of the Hudson River, that tidal stream must be crossed by the great aqueduct of 500 million gallons daily capacity that is to bring the water to the city.

Not only has the problem of the river crossing engaged the earnest attention of the engineers of the board, but it has attracted the notice of the general public as well. In fact, the latter has probably shown more interest in it than in any other engineering feature of the board's work.

The purpose of this paper is to describe in a general way the problem and the field studies which determined the location of the crossing, as well as some features of the construction. It is not intended to go into the details of the several phases of the work, as the scope of the paper will not permit it. A detail description of the field work is admirably presented in a paper entitled "Studies and Explorations for the Hudson River Crossing of the Catskill Aqueduct," prepared by Messrs. Samuel D. Dodge and William B. Hoke, Assistant Engineers, Board of Water Supply, for the Municipal Engineers of the City of New York, and published in the 1910 Proceedings of that society. The details of design of tunnels of the type adopted for the Hudson River crossing are described in a paper entitled "The Design of Pressure Tunnels of the Catskill Aqueduct," by Mr. Thomas H. Wiggin, Senior Designing Engineer, Board of Water Supply, and published in the 1909 Proceedings of the same society.

The Board of Water Supply, which is charged by Chapter 724 of the Laws of 1905 with the duty of securing the much-needed additional supply of "pure and wholesome" water, was organized in the summer of that year, and in the following autumn, on the recommendation of its chief engineer, Mr. J. Waldo Smith, a vice-president of this Association, decided on the Catskill sources.

The general plan, briefly stated, was to develop the watersheds of Esopus, Rondout, Schoharie, and Catskill creeks in the order named, together with a number of smaller sheds adjacent to them; to build an aqueduct of 500 million gallons daily capacity from the Esopus Creek to a distributing reservoir at Hill View near the city line; a storage reservoir of 40 000 million gallons capacity near Valhalla, 14 miles north of Hill View, known as the Kensico Reservoir; and trunk conduits to the boroughs of the Bronx, Brooklyn, Queens, and Richmond.

The importance of the river crossing was early realized. In his report to the board of October 7, 1905, the chief engineer referred to it in this language:

"The crossing of the Hudson River by the 500-million-gallon aqueduct is one of the most important matters for immediate consideration, and borings were begun recently to determine the character of substrata at the point where the surface indications give the greatest promise of favorable conditions. The work of boring is now in progress.

"Studies on the surface of the ground have indicated that it will be feasible to locate this crossing near the village of New Hamburg, as shown by the accompanying map.

"Either one of several types of river crossing may be made, according to the character of the bed of the river revealed by the borings."

The type of structure to be used for the crossing was given early consideration. Among other types so considered were:

1. A bridge at or below hydraulic gradient. The height of such a bridge was limited by the hydraulic gradient, about 410 ft. above the river, and the clearance which would be demanded by the War Department, probably 135 ft. above high water. Unless a pier was permitted in the channel, the span of the bridge would be at least 2 000 ft. at the narrowest location considered.

2. Steel or cast-iron pipes laid in the bed of the stream. Several lines of the largest practicable sizes would be required, both to obtain the necessary capacity and to insure safety. The latter consideration would also demand that the several lines be laid a reasonable distance apart so that if one should break under the high-service pressure it would not injure the others.

3. One or more tunnels driven by use of compressed air through the mud of the river bottom. The depth of such tunnels would be limited by the pressure under which the men constructing them could work, — not much over 100 ft. below tide. This construction would require a location where the depth of water was such as to provide a natural or permit an artificial covering for the tunnel during the driving of the latter. The ordinary cast-iron lining employed for transportation tunnels of this type of construction would not be sufficient against the enormous bursting pressure of the aqueduct tunnel. If such a lining was needed as a means of construction, an additional inner lining of steel would be necessary before putting the aqueduct in service.

4. A tunnel deep enough in sound rock to be secure against a break from internal pressure, lined with masonry to provide better hydraulic properties, and made tight against outward leakage through seams which might exist in the rock.

After careful consideration the rock tunnel type was early decided on for reasons of safety, durability, and economy. This type has come to be known as a " pressure tunnel," and is so called on the Catskill work to distinguish it from tunnels located on the hydraulic gradient, which are known as " grade tunnels."

With the question of type thus decided, efforts were directed towards finding the best location for the river crossing. It should be remembered that in determining the location, weight had to be given to the land approaches as well as to the river crossing itself; for instance, the advantages of a certain crossing might be apparent when considered by itself, but the land construction leading to it might be so expensive or otherwise objectionable as to destroy these advantages. This is made clear when it is realized that the extreme locations seriously considered for the crossing were 22 miles apart, and that a change from one extreme

to the other would affect the location of more than 40 miles of aqueduct.

In search of the crossing the river was studied from Pegg's Point, $2\frac{1}{2}$ miles north of New Hamburg, to Anthony's Nose, in the lower part of the Highlands. A preliminary study showed that any crossing north or south of these points would mean a lengthening of the total line of the aqueduct, and consequently greater expense in construction and maintenance, without compensating advantages. (See Fig. 1.)

The lines considered as the most favorable ones formed themselves into two distinct groups, called for convenience the "New Hamburg group" and the "Highland group." The former included as its most desirable routes those crossing at Pegg's Point, New Hamburg, and Danskammer Point, and similarly the Highland group included the Plum Point, Storm King, Little Stony Point, West Point, and Anthony's Nose routes, so called from the localities where they crossed the river. Between the two groups mentioned the topography did not lend itself to a favorable crossing. The river was broader, reaching a maximum width of more than $1\frac{1}{2}$ miles in Newburgh Bay, and the land approaches were not so favorable as those north and south of this gap.

The first general route for the Catskill Aqueduct, laid down tentatively in 1905, contemplated that the water would be drawn from the east end of the Ashokan Reservoir, in the Esopus watershed, near West Hurley. This brought the New Hamburg group into prominence, as a crossing in their vicinity would mean a far more direct line than would any crossing in the Highlands. This advantage of the New Hamburg group disappeared to some extent when further studies in more detail showed the advisability of locating the headworks of the aqueduct near Brown's Station at the dividing wall between the two basins of the reservoir. In addition, subsurface explorations made in the meantime for the pressure tunnel crossings of the Rondout and Wallkill valleys indicated better geological conditions farther upstream than at the crossings first proposed. Similar explorations in the valley of Fishkill Creek on the east side of the Hudson showed the presence there of a zone of disintegrated limestone extending to a great depth, which it would be advisable to avoid with a pressure

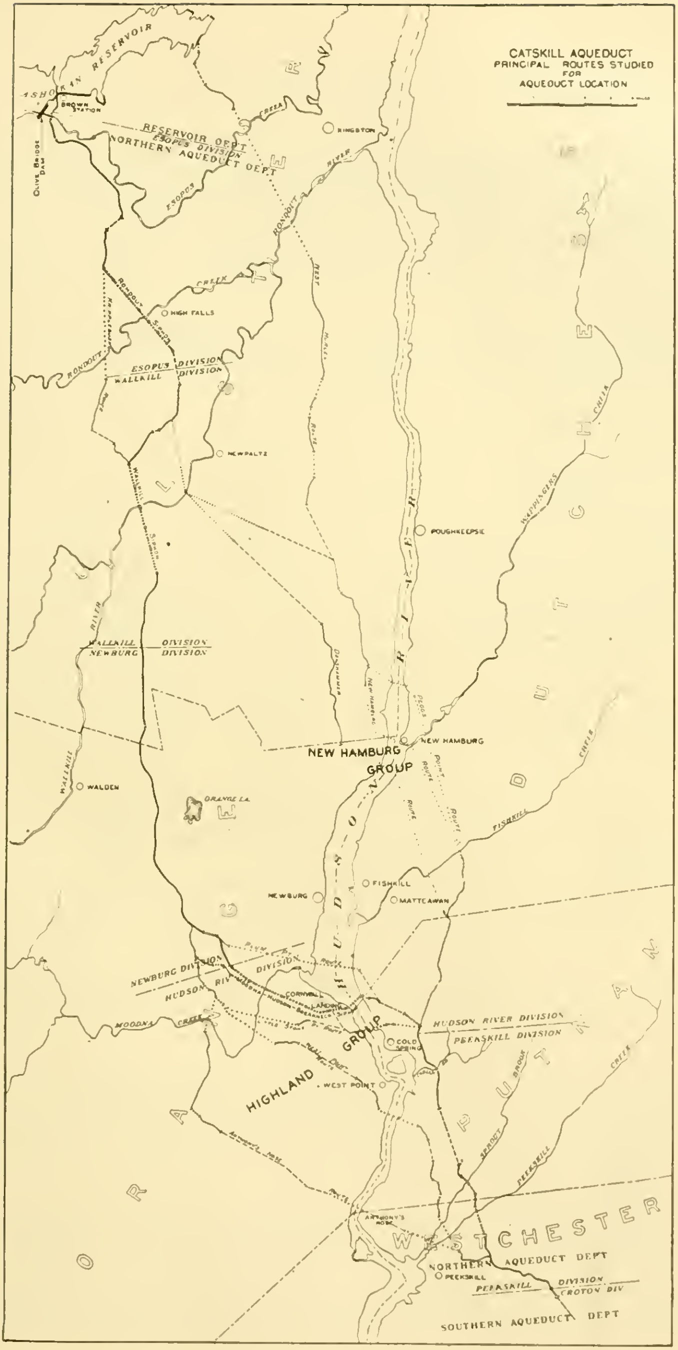


Fig. 1.

Principal Routes studied for Catskill Aqueduct, Northern Aqueduct Department.

tunnel. This valley would not have to be traversed if the crossing of the river could be made in the Highlands. With these and other considerations in mind it was shown that any one of the Highland routes would be substantially cheaper to construct than the Pegg's Point route, regarded as the most desirable one of the New Hamburg group.

Among other features sought for the crossing proper were, (1) favorable geological conditions, (2) a narrow channel, and (3) a shallow bedrock gorge. The Highland routes had no decided advantage in regard to the narrow channel, and the depth of the bedrock gorge was supposed to be greater there than in the vicinity of New Hamburg. The advantages from a geological point of view, however, were with the Highland group.

The geological features of the problem were carefully studied and reported on by the board's consulting geologists, Prof. W. O. Crosby, of the Massachusetts Institute of Technology, and Prof. James F. Kemp and Dr. Charles P. Berkey, of Columbia University. Dr. Berkey, in a report published as New York State Museum Bulletin 146, entitled "Geology of the New York City (Catskill) Aqueduct," explains the problem and gives the results of his studies of it in a very interesting form.

It was essential that the rock surrounding the tunnel be not only strong and watertight, but durable. Limestone especially was a formation to be avoided if practicable, because of its uncertain characteristics and its tendency to develop caves and fissures. At any one of the New Hamburg crossings the tunnel or the shafts would have to penetrate this rock. At the West Point and Anthony's Nose crossings the presence of limestone under the river bed was suspected, although not proved. At the Storm King and Little Stony Point locations, however, there was every indication that granitic gneiss formed the entire rock floor of the river, of the same excellent quality as that found on both shores. This favorable condition carried considerable weight in deciding on the location.

A careful summing up of the advantages and disadvantages of the various routes resulted in the adoption of the line crossing the river from Storm King Mountain on the west to Breakneck Mountain on the east side. Since the summer of 1906, therefore,

work has been in progress at this crossing and its land connections, preparing for and carrying on the construction.

The Hudson River crossing, as finally located, is part of one long inverted siphon extending from the point where the aqueduct leaves the hydraulic gradient at the downtake shaft of the Moodna siphon, nearly 5 miles northwest of the crossing, to the uptake shaft on the slope on Breakneck Mountain, about 800 ft. east of the crossing. (See Fig. 2.) The total length of this pressure section of

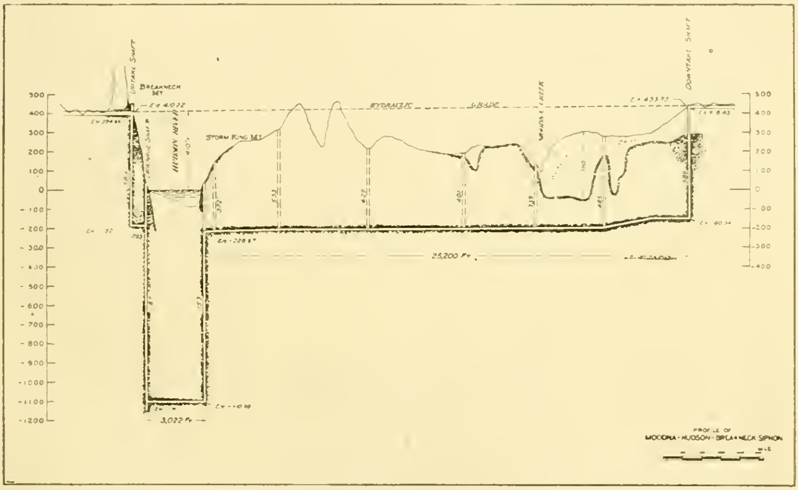


FIG. 2.

PROFILE OF MOODNA-HUDSON-BREAKNECK PRESSURE TUNNEL, CATSKILL AQUEDUCT.

tunnel, including the river crossing, is 29 015 ft., or 5.5 miles. The downtake shaft drops 594 ft. below hydraulic gradient to elevation −160.34. The tunnel descends thence on grades varying from −2% to 0% to the west shaft of the river crossing, which it meets at elevation −228.72. This shaft drops to elevation −1111. The river tunnel drops 3 ft. more to its junction with the east shaft to elevation −1114. The water will rise in the east shaft to the land tunnel at elevation −192, which is level to the uptake shaft on

Breakneck, and will rise in the latter 602.22 ft. to hydraulic grade. The tunnel elevations here given refer to the invert grades. It should be noted in passing that all the levels of the Board of Water Supply are referred to the datum plane of the United States Coast and Geodetic Survey, which is mean sea level at Sandy Hook. All of the permanent shafts of the tunnels, are circular. The Moodna tunnel and downtake shaft will be finished 14 ft. 2 in. in diameter; the other shafts and tunnel, 14 ft. in diameter. The tunnel and permanent shafts will be lined with concrete. The hydraulic gradient at the river crossing is approximately 410 ft. above tide, or nearly twice as high as the floor of the railroad bridge crossing the river at Poughkeepsie, which is about 212 ft. above tide. Shaft 7 of the Moodna siphon will be maintained as a permanent shaft so that access may be had to the tunnel on the west side of the river in the vicinity of the crossing. This paper is devoted particularly to that portion of the long siphon between the river shafts, or the river crossing itself.

The location selected is at the "north gateway of the Highlands," one of the most picturesque points along the Hudson. The almost precipitous granite slopes of Storm King and Breakneck, each rising over 1 200 ft. above the river, encroach on the channel, contracting it to a width of 2 800 ft. between shore lines. There Nature has left nothing to be improved upon, and any structure that man could build would only tend to mar the spot. The spanning of the channel with a bridge would be regarded by many almost as a sacrilege.

On the line selected the rock outcrops down to the water's edge. The river reaches a maximum depth of 85 ft. about one third of the way out from the west shore. The ordinary tides have a range of nearly 3 ft., the mean level being from 0.75 ft. to 2.25 ft. above mean sea level, depending on the season of the year and the flow of fresh water from above. The water is comparatively fresh in the spring of the year when the river's tributaries are flowing full. At such times it is available for boiler use. As the season advances and the supply of fresh water diminishes, the salt water is carried farther and farther up the river with the tides and the water becomes brackish, particularly at flood tide. Analysis of a sample taken at flood tide on August 15, 1911, showed 1 380 parts per

million of chlorine and 2 978 parts total solids, while a sample taken June 12, 1911, at end of the ebb tide showed 14.5 parts chlorine and 111 parts total solids.

Dr. Berkey in the bulletin mentioned refers to the Storm King location as follows, on page 104:

"This is wholly in massive and gneissoid granite. The rock is the most massive and substantial body of uniform type found in the Highlands. The course of the river indicates some weakness in that direction. This weakness may be some minor crushed zone or even the jointing alone that prevails throughout the exposed cliffs. But there is no direct evidence of faulting, cutting the line, and such crushing as may be encountered is believed to have originated at such depth and under such conditions as to cause no large disturbance. The freedom of this formation from all bedding structures and natural courses of underground water circulation on a large scale is an additional factor. There is absolutely no other place, within the region, where the Hudson River can be crossed from grade to grade in good ground of a single type with so great probability of avoiding all large lines of displacement."

And on page 106:

"The rock of Storm King Mountain and of Breakneck Ridge at the Hudson River crossing is a very hard granite with a gneissoid structure of variable prominence. The color varies from grayish to light reddish and the structure is always coarse passing into pegmatite facies that occur as stringers or irregular veinlets. The grayish facies is of slightly finer grain and more gneissoid. Those portions that have been sheared are still darker. There are many joints at the surface running at various angles and an occasional slickensided surface. The mass is cut by several dikes of more basic rock (diorite) of widths varying from a few inches to eight feet. These dikes are somewhat more closely jointed than the granite and consequently a little more readily attacked by the weather. But where protected they are equally substantial for underground work.

"The chief variation from this condition is where crushing or shearing has induced metamorphic changes. Wherever bed rock has been reached at this point and to such depths as workings have penetrated the rock is of this type."

With the type of structure and the location of the crossing decided on, it remained to fix the depth of the tunnel below the

river bed and to work out the designs of the tunnel and its appurtenances. The explorations to determine the depth were made by means of (1) wash borings, (2) vertical and inclined core borings on the shores and vertical core borings in the channel of the river, and (3) test shafts on the shores of the river from chambers in the sides of which inclined diamond drill borings were drilled under the bed of the river.

Early in the progress of the explorations, before the location was determined, agreements were made for putting down wash borings and core borings in the channel and along the shores. The wash borings were practically finished and the core borings were begun before a decision as to the location of the crossing was made.

Under agreement with Mr. F. W. Miller, of New York, wash borings were made on fourteen cross-sections of the river for the purpose of getting preliminary information as to the depth of the material overlying the rock. The outfit required for them was a small scow carrying a derrick and hand winch and a hand pump, together with the necessary wash rods and casings. They could be made quickly but only to limited depths, 100 to 200 ft., where they were stopped by bowlders or hard material. Sometimes two or three such holes could be put down in a day. Usually the casing was only washed down 30 ft. or so in the mud of the river bottom, far enough to guide the 1 in. wash rod, the latter going down the rest of the way without any casing. Under such conditions it was not practicable to use powder when an obstacle, such as a bowlder, was met, as the casing did not extend far enough down to maintain the hole when the powder was exploded. Only negative results were obtained, showing that ledge rock did not exist above the bottoms of the holes. It was not advisable to use any more careful or painstaking methods with these wash borings, as no positive information of the position of the rock could have been obtained by means of them alone. They cannot be relied upon for this purpose. A set of holes put down on the present Storm King line reached consistent depths of about 160 ft. It would have been unfortunate had these results been accepted as showing the position of the rock. The core borings made afterwards proved it to be at least 768 ft. deep.

In addition to a number of diamond drill borings, inclined and vertical, made on the shores of the river at Pegg's Point, New Hamburg, and Storm King to ascertain the character and formation of the rock, vertical core borings were made in the channel on three cross-sections, viz., Pegg's Point, Little Stony Point, and Storm King. All of this work was done by contractors under agreements with the board.

At Pegg's Point three holes reached and penetrated rock at depths of 92 ft., 241 ft., and 165 ft. respectively. Two of them were in Hudson River shale, a sedimentary rock composed of alternate layers of slate and sandstone, and one in the formation known as Wappinger's limestone. The distance between the two holes of 92 ft. and 241 ft. depths was 1 040 ft. In this gap was the fault line which follows the river at this point, where the preglacial gorge was probably much deeper then the depths reached by the drills.

At Little Stony Point three core borings were started in the season of 1906, but were not successful in reaching rock. One of them was lost by action of the elements, one by accident, and one was abandoned when it was found advisable to concentrate work on the Storm King line.

Naturally most of the river core borings have been made on or in the vicinity of the line at Storm King on which the tunnel is now being driven. Here 12 holes were started; 3 of them reached and penetrated ledge rock, 2 were lost through action of the elements, 2 were destroyed by tows navigating the river, and 5 were abandoned for one reason or another before they had reached ledge. These borings developed in a fairly satisfactory way the rock profile for a distance of 800 ft. from the east shore. Beyond this point nearly to the outcrops on the west shore the rock profile is not positively known. The river holes were unsuccessful in proving it, and gave only negative information of its position; that is, that it was below the depths reached by the borings. One of these holes located in the middle of the channel reached a depth of 768 ft. last December, when, after two seasons' work, operations were discontinued on account of the approach of winter. At this depth the casing was in a nest of bowlders which possibly immediately overlie the ledge.

The difficulties of making such borings in the channel of a navigable river were very great. Among other factors affecting the work should be noted the depth of the water, which, as before stated, reached a maximum of 85 ft., the necessity of doing most of the work from floating platforms, the varying currents induced by the tides, and the danger from storms and the collision of river craft. Considering the character of the work and the conditions under which it was necessarily done, it is perhaps not remarkable that more successful results were not obtained. Generally speaking, the material lying between the water and ledge is silt and clay, then a mixture of sand and clay with gravel increasing in coarseness with the depth, and bowlders. (Plate I, Fig. 2.) Little trouble was encountered in putting down the holes until a depth of between 300 ft. and 400 ft. was reached, when the bowlders interfered and caused delay. It was necessary to break them up with chopping bits or dynamite before the casing could be forced below them. At times the diamond bit was used to bore a hole through a large bowlder which could not be removed by the above means. Then it was broken by powder put into the diamond drill hole and the shattered pieces forced out of the way or removed. The removal of such a bowlder was sometimes the work of several weeks. When ledge was finally reached and the casing seated on it, most of the troubles were considered to be over, as the drilling into it with a diamond bit was a comparatively simple matter. An excellent description of this boring work is found in the paper of Messrs. Dodge and Hoke, before mentioned. The following extracts are quoted from it.

"All of the core-boring work on the river at the Storm King line has been under Contract No. 1, with the American Diamond Rock Drill Company, but has been done by their assignees, the Phœnix Construction Company.

"The equipment which experience has shown to be best and which is now in use is a piledriving scow 35 ft. by 100 ft. with ways 60 ft. high; a hoisting engine of 40 h.p. with two 7-in. by 10-in. cylinders and two 12-in. drums; two 12-in. by 7-in. by 12-in. pumps with capacity for 100 gal. per minute each at 120 lb. pressure, and a 60-h.p. boiler; casing and wash pipe of 18-in. and 14-in. steel-welded pipe, and 10-in., 8-in., 6-in., 4-in., $2\frac{1}{2}$-in., and 2-in. extra heavy wrought-iron drive pipe with screw joints and

Fig. 1.

Hudson River Crossing, Catskill Aqueduct, looking West towards Storm King Mountain. Core Boring Rigs in Channel.

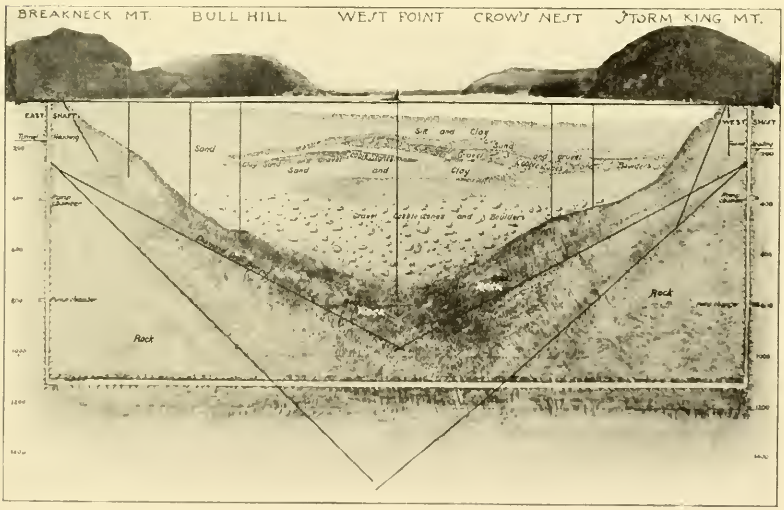


Fig. 2.

Panoramic View and Cross Section on Line of Hudson River Crossing of the Catskill Aqueduct.

extra long sleeve couplings; a drilling machine; $1\frac{7}{8}$-in. rods, and enough diamonds for two bits. When the casing is surely seated in ledge and drilling under way, the large scow and other equipment for wash boring can be dispensed with, the drilling machine being carried on a platform clamped to the casing, and pump and boiler kept on a scow about 20 ft. by 30 ft.

"The scow is kept in position by at least six anchors at bow, stern, and four corners; these must be from two to three tons each and have leads of 400 to 500 ft. of $\frac{7}{8}$-in. wire cable. The severe gales and rough water encountered at times make it hard to keep the scow exactly in position, while any movement, if it is toward the hole, is likely to bend the standing casing and destroy the boring.

"The general method of boring is to sink first a line of large casing as far as possible without too severe driving, then to put down the next smaller size inside of it, 'telescoping' as it is called, and continue downward again, the telescoping of casing being repeated when necessary until bedrock is reached. A line of casing, of course, encounters skin friction against the drift material only below the bottom of the next larger casing, and in general an advance of 100 ft. or more should be made with each size, though the first two sizes should make considerably more than that in the fine material which lies on top. The importance of not having too much frictional resistance on a line of casing comes from the necessity not only of moving the line down but of being able to draw it back, so that its end will be out of harm's way when blasting is done, hence care is taken against forcing when much resistance is felt. In the early work before the great depth of the gorge was known, and when the contractor knew less of how to do this kind of boring, the mistake was made of starting with too small casing and so coming down to the smallest size practicable while still a long way from rock; this made the last of the work on these holes excessively difficult, and one of them had to be abandoned in an unfinished condition for this reason. The latest and deepest holes have been started with 18-in. casing; six reductions are then possible.

"The casing is lowered and raised by a wire cable fall passing over the sheave at the top of the pile falls to the drum of the hoister. As the casing goes down, it is added to in 20-ft. lengths, the additional piece being supported by the fall while the men screw it into the coupling at the top of the line. Great care is taken with the joint, the coupling is extra long, and an effort is made to have the pipe ends meet, so that in driving the blows of the hammer will not be carried by the threads entirely.

"The first material encountered is mud and silt, and the large casing, being very heavy, goes into it for the first 50 ft. very

easily. When light driving ceases to have an effect, a 4-in. pipe is put down inside and connected with the pump by hose and a powerful stream of water forced through it, to stir up the material just below the bottom of the casing, the water returning inside the casing and bringing up the lighter material with it. The casing is at the same time pounded lightly by the piledriver hammer, which has a hole in its center through which the wash pipe passes."

From the information obtained from these borings, the inclined holes to be described later, and a study of the physiography of the vicinity, Professor Kemp and Dr. Berkey concluded that the cross section of the bedrock gorge resembled a broad U, while Professor Crosby advanced the theory that it took the form of a wide-flaring V. Its greatest depth, of course, was between the bottom of the deepest river hole (768 ft.) and the depth at which the upper pair of inclined holes crossed each other (about 955 ft.).

When the explorations for the crossing were begun in 1905 it was realized that before actual tunneling was started under the river it would be advisable to explore the underlying rock from shore to shore with diamond drills to ascertain its character, and to show whether there existed any faults or zones of decayed or broken rock or water-bearing seams that would make the driving of a tunnel impracticable. It was realized that vertical borings in the channel, while furnishing a fairly good cross section of the preglacial gorge, would not give this essential information. In the first core boring contract, awarded February 7, 1906, therefore, a provision was made for six inclined borings to start on the shores of the river and extend under the channel to the middle. It was believed that a careful watch of these holes while they were being drilled and a study of the cores recovered would give a very good idea of the rock to be encountered in tunneling, and that some of the uncertainties of the latter would thereby be eliminated. After the first vertical borings had indicated a greater depth of bedrock gorge than was anticipated, it was found to be impracticable to start the inclined borings from the shores. The great inclinations at which they would have had to be drilled in order to keep them in the rock would have forced them too far below the river bed to be of any use for the purpose intended. It was, therefore, decided to drill them from chambers to be excavated in the sides

of test shafts at an elevation low enough to permit a flatter hole. When the sinking of the test shafts, hereinafter described, was begun in the early part of 1907 the intention was to excavate the drill chambers at about elevation — 550. The abandonment of the work by the contractor in the latter part of the same year, when only half of this depth had been reached, resulted in so much delay that when operations were resumed by the city with its own forces, in 1909, it was decided to excavate the drill chambers at the bottoms of the shafts, as they then were, before sinking deeper, in order that the drilling could be started and the needed results obtained at as early a date as practicable. This meant that the first drill holes were started at elevation — 281 and — 251.2 in the east and west shafts respectively. Two holes were drilled from each chamber, the first or lower pair being started at angles of 43° with the horizontal in the east chamber and 38° in the west chamber, and passing each other under the middle of the river approximately 1 500 ft. below tide. The second pair of holes were later started at elevations — 279.7 and — 245.8, and at inclinations below horizontal of 22° 53′ and 23° 40′ in the east and west chambers respectively. These holes crossed each other under the river about 955 ft. below tide.

When it was determined at what points the borings should be made, a form of agreement was prepared for a pair of holes to be drilled until they crossed under the bed of the river. Bids were invited from a number of concerns experienced in such work, payment to be made under two items: No. 1 to include the first 900 ft. of any hole, or for drilling the remainder beyond 900 ft. of any hole not included in Item 2; No. 2 included the remainder beyond 900 ft. of any hole which either terminated within an ordered zone or passed in solid rock above the ordered zone a hole from the opposite side of the river. The zone as indicated on the contract drawing was defined by curved lines originating at the beginning of the hole in each chamber. The upper curves intersected about elevation — 1130, and the lower ones about elevation — 1440 under the middle of the river. The zone was fixed with reference to the bedrock profile of the gorge as far as it was then known, and was designed with the idea of having the borings cross at as high an elevation as

was considered safe. The work was awarded to the low bidder, Messrs. Sprague & Henwood, of Scranton, Pa., who bid \$6.50 and \$10 per foot respectively for Items 1 and 2, and who promptly undertook the work. The hole in the east chamber was begun on June 1, 1909, and in the west chamber on July 29, 1909. The east hole was started at an angle of 43° and the west one at 38° with the horizontal, as before stated. These angles were selected by the contractor with the idea that the drill holes would have a tendency to turn up and thus carry them at the finish into the desired zone. Precautions were first taken to guard against this tendency to turn up too rapidly, as described by Messrs. Dodge and Hoke in the following extract from their paper regarding the first hole drilled.

"The east shaft chamber was ready in May, 1909, and hole No. 1/A-74 was started June 1. The machine, Sullivan diamond B drill, rated for 3 000 ft. of hole, was set for an angle of 43° below the horizontal, that being practically the slope of the tangent to the zone. The agreement called for a hole starting not less than $2\frac{1}{16}$ in. in diameter. Sprague & Henwood decided that the safest way to get the holes to such depths was by two successive reductions in size. The holes were started with $2\frac{1}{2}$-in. bits, reduced to 2-in. and later $1\frac{3}{8}$-in. As a precaution against a heavy flow of water, the drilling was carried on through a 3-in. gate valve attached to a 3-in. pipe grouted in the rock. To seat the pipe, the first 7 ft. of the hole was bored with a 4-in. bit.

"The drillers desired to drive the first several hundred feet as nearly straight as possible on the line set, so that great care was taken with the drilling apparatus to produce that result. The $2\frac{1}{2}$-in. bit was set as usual with eight diamonds, four to cut hole, four to cut core, and all to cut ahead, but was set to as small a clearance as possible. The diamonds projected only $\frac{1}{64}$ in. outside. The bit, shell, core barrel, and 60 ft. of rods immediately following were all the same size, actually $2\frac{11}{16}$ in. in diameter. These rods were termed guide rods. Behind the guide rods, 2-in. rods were coupled on as needed. Despite all care, a survey made when the hole was at a depth of 177 ft. showed that the boring was turning downward. The guide rods were taken off so that the sagging of the smaller rods behind the core barrel would force the bit upward. Another test made at a depth of 280 ft. gave proof that the rods were holding to a straight line and with perhaps a slight upward tendency. The hole continued at approximately this inclination, which was a trifle less than the initial slope, to a depth of 641 ft.

"Here the reduction was made to a 2-in. bit. Here, also,

whether by means of forcing the rods, as claimed, or by chance, began the first upward turn of the hole. This upward movement seemed to be increased by the use of a tapered core barrel along with a forcing of the rods, until at a depth of 1 398 ft. the survey showed the inclination at that point to be about 37° 20′. Then began another downward curve to the end.

"A small flow of water was encountered in hole 1 A-74 at a very small depth. This gradually increased as drilling progressed until at the time of the first reduction in size the flow from the open hole was 50 gal. per minute. At a depth of 734 ft. the flow had reached 90 gal. per minute and was hindering the work.

"A careless drill runner nearly ruined the hole at this point as a direct result of the back pressure exerted by the water. He did not keep his pump going hard enough to force water through the rods, and the bit was burned fast in the rock. The rods were detached from the bit, the $2\frac{1}{2}$-in. hole was extended to 734.3 ft. by reaming, and the 2-in. bit, or what was left of it, was recovered as core with the steel and diamonds fused into the rock.

"In order to shut off the water, $2\frac{1}{2}$-in. flush-joint casing with several diamond chips set into its lower end was placed in the hole. It was turned by the machine like rods until the bottom was burned fast to the rock as the bit had been. The water flow was reduced to 5 gal. per minute, but did not long remain so small. By the time 1 085 ft. had been drilled the open hole was sending a solid stream of water, 180 gal. per minute, 10 ft. from its mouth into the chamber. With this flow the last hundred feet of rods need not be pulled from the hole when core was being recovered; they slid out. No other advantage could be credited to the water which made drilling unpleasant work until the hole was again cased at a depth of 1 234 ft. with 2-in. flush-joint casing and again reduced in size. The water flow in this hole was one of the deciding elements for reduction in size. The quantity was lessened to 10 gal. at this final casing and did not increase beyond 70 gal. per minute, which was judged to be a limit of flow under the existing head from the now long hole.

"At a depth of 1 834 ft. the bit was again burned fast. Over two months' work failed to remove it. Diamonds, collectively valued at over $1 500, and about 600 ft of small rods were lost. Hole No. 1 A–74 had not entered the ordered zone and did not quite reach the center of the river."

The hole from the west chamber was drilled by the same general methods. Little trouble was caused by water, the maximum flow recorded being only 5 gal. per minute. The general tendency of the hole was downward, the inclination below horizontal at the finish

being 44° 47′, or 6° 47′ steeper than at the start. On account of the abandonment of the east hole before it had reached the middle of the river, due to the burning fast of the bit, it was necessary to carry the west hole past the center point in order to pass it horizontally beyond the end of the east hole. It was driven, therefore, to a total depth of 2 051.6 ft., which is believed to be an unprecedented depth for such a boring in this section of the country.

The first pair of holes having proved beyond question the existence of sound rock under the entire width of the river channel, it was next decided to drill two more similar borings from the same chambers, but at flatter inclinations with a view to having them cross under the middle of the river between elevations −850 and −1 050. Should they succeed in passing in sound rock through this higher zone the elevation of the under river tunnel could be fixed with reference to them. Accordingly, another agreement, No. 77, was prepared and the work was again awarded to Messrs. Sprague & Henwood, the low bidders. The holes were drilled at inclinations of 22° 53′ and 23° 40′ in the east and west chambers respectively, as before stated. The east hole was drilled to a depth of 1 651.4 ft. between April 5 and August 4, 1910, and the west hole to a depth of 1 652.1 ft. between April 20 and August 25, 1910. Although they were aimed so high as to have but slight clearance in places below the rock surface indicated by the core borings, they remained in excellent rock throughout and crossed each other about at elevation −955. It is an interesting fact that the east hole, though much above the former hole drilled from the same chamber, and consequently nearer the river bed, developed a much smaller flow of water.

Much credit is due Messrs. Sprague & Henwood for the successful completion of these borings. The difficulties and discouragements met and overcome during the progress of the drilling were far greater than usually attend a work of this character. It is easy to imagine the failure of the task if placed in the hands of men of less experience and courage.

No attempt was made to ascertain the change of strike or horizontal direction of the borings, as this was not regarded as necessary. Surveys were made from time to time, however, of the inclination or dip of the holes. A knowledge of the methods em-

ployed in these surveys may be of interest, and I cannot do better than quote again from the paper of Messrs. Dodge and Hoke:

"Two methods, known as the hydrofluoric acid test and the pressure gage test, were employed.

"The hydrofluoric acid test for inclination is based on the power of hydrofluoric acid to etch glass and the principle whereby the surface of a liquid at rest under the action of gravity assumes a horizontal position. At various known depths along the boring to be surveyed, readings for the inclination are obtained from a horizontal etched line on a glass tube whose axis is parallel with the direction of the hole. These inclinations constitute a series of tangents to a compound curve which is the line of the hole itself. Of course, this method gives a determination only, as it were, in dip and not at all in strike.

"An ordinary homeopathic pill vial, $\frac{7}{8}$ in. outside diameter, $\frac{13}{16}$ in. inside diameter, and $4\frac{5}{8}$ in. long, containing a solution of nine parts by volume of water and one part by volume of hydrofluoric acid, is placed in a water-tight steel shell, about a foot long, which is the same diameter as the rods in use and is bored to exactly hold the bottle. The shell or tester is coupled to the rods and lowered into the hole. During the time required for lowering the rods no definite line is etched because the rods in turning apply the acid to all sides of the tube and because the solution is made weak in order to reduce the action as much as possible. When the required depth is reached the rods are clamped and allowed to rest long enough for the acid to do its work. At great depths the period at rest required to give a well-defined line is about an hour. The rod is rapidly withdrawn and the acid emptied from the recovered tube.

"For the survey of these holes, the angles were read by placing the record tube in a machine constructed for the purpose. The tube was clamped to a revolving pivot in such manner that the etched line and the side of the bottle could in turn be sighted in parallel with a straight edge which is the diameter of a graduated semicircle protractor. A reading was taken of the position of a needle which was rigidly connected with the pivot and played over the graduated arc. The difference in readings gave the observed angle. Owing to the effect of capillary attraction on the acid solution, the observed angle was not the true angle. A minus correction varying from 4° for a reading of 26° 24′ to 8° for a reading of 52° 05′ had to be applied to obtain the true slope. A correction diagram was prepared by taking readings on tubes exposed to known slopes. The final accepted angle was an average of twenty-four readings made by two independent observers. Tests were made not more than a hundred feet apart.

"The hydrofluoric acid test was the most used method of making surveys, but it had one objection, — one erroneous reading changed the position of all the hole below it. It is apparent therefore, why the precautions above described were taken to eliminate the danger of such an error.

"The other method tried was that of a recording pressure gage, designed and made by Dr. Herbert T. Kalmus and Mr. Gilbert N. Lewis, of the Massachusetts Institute of Technology. The gage was made so that it could be inserted in a hole and lowered to the desired point by means of a pliable wire cable. From the flow of water, the holes were always full, and the object was to measure the static head at any point, preferably near the bottom, as the location of the ends of the holes was most important. Accordingly, the gage was designed for only heavy pressures.

"The gage consisted of a flat steel tube with a certain resisting power which was placed in the lower end of the inch tube encasing the whole gage, so that it could be exposed to the external pressure of the water. To the top of the flat tube and in a water-tight compartment of the casing tube was connected a glass capillary tube which opened into a small cup. The flat steel tube and the glass tube were filled with mercury when the instrument was ready for a test.

"Now when the gage was subjected to pressure the steel tube was compressed and forced mercury into the cup from which it could not return when the pressure was removed. Then by simply reading the height of mercury in the tube, the pressure to which the gage had been subjected was known. The instrument, of course, had been calibrated by applying known pressures and marking the heights of mercury.

"The principle of obtaining the vertical distance of a point at known depth below the top of the hole was excellent, but the machine did not always work well under the conditions which obtained. The gage recorded only the highest pressure, and it was practically impossible to lower the gage so that higher pressures than that of the static head would not be recorded. The movement of the gage through the water affected the pressure. All sorts of schemes were tried to offset the disadvantage. Even when the pressure was allowed to reach the flat steel tube only through a 3-ft. capillary tube, impact pressures were sometimes recorded, in which cases the machine would not check either itself or the survey by the hydrofluoric acid test, and no credence could be placed on the results, although the principle of the method was a better one."

It was decided to sink the two test shafts before referred to as a part of the scheme of exploration. They were so designed as to

form part of the permanent construction should the explorations prove the feasibility of the location. The upper 225 ft. or so of the west shaft above the proposed connection with the land tunnel were made rectangular, to be closed later, that portion being of use only as a construction shaft. Below the land tunnel the west shaft was made circular for use as a waterway shaft, of a size to finish inside of concrete lining, with a diameter of 14 ft. The east shaft was made circular from the top down with a view to lining it throughout and maintaining it as a permanent shaft, that portion above the proposed land connection being intended as a pumping shaft to be used for unwatering the siphon when necessary in the future. Both shafts were so located as not to interfere with the present or proposed future positions of the Hudson River and West Shore railroad tracks. The west shaft is about 120 ft. back from the river at the foot of the north slope of Storm King Mountain, where the elevation of the ground surface was about +40. The east shaft is 100 ft. from the river shore on the projection of Breakneck Point, where the elevation of the ground was +31.5. Through Breakneck Point the Hudson River Railroad passes in a rock tunnel, and the shaft is between this tunnel and the public road which skirts the river shore. The location of the east shaft was on a steep rock slope, and before beginning the sinking the site was excavated in open cut to the approximate level of the road, or about elevation +12. The shafts are 3 022.3 ft. apart on centers, and the tunnel line between them is straight.

Ground was broken for the east shaft on February 14, 1907, and for the west shaft on March 7, 1907. Under the agreement with the contractor, he was to go, if required, to elevation −650 with both shafts. At the time the agreement was signed it was not known even approximately what the depth of the rock gorge was, the deepest boring in the river at that time having reached a depth of only 482 ft. Elevation −650 was fixed as the maximum depth we were then justified in sinking the shafts with the information at hand.

On December 7, 1907, when the east shaft was down to elevation −249 and the west shaft to elevation −226, the contractor stopped work. The complications which followed delayed the resumption of the work of sinking more than a year, when it was started again

by the board with its own forces under the immediate supervision of the division engineer, Mr. William E. Swift. By this time the river borings had proceeded far enough to indicate a much greater depth of rock gorge than was supposed when the shafts were started, and it was decided to make preparations to sink them deeper than was provided in the contract. A depth of 1 200 ft. below tide was tentatively fixed until more positive information from the boring operations should be available. It was also decided, as before stated, to begin the inclined borings under the river as soon as chambers could be prepared for them at the bottoms of the shafts.

Before resuming actual excavation, the derricks used by the contractor were taken down and headframes constructed over the shafts. These frames were designed so that they could be used not only for completing the shafts, but for driving and lining the tunnels under the river. New hoisting engines were installed of a much heavier type than those employed before. A new air-compressing plant was assembled for the west side, and the compressors, which the contractors had used for both shafts, were grouped for use at the east shaft. Other additions and improvements were made in the plant with a view to meeting the requirements of greater depth and to insure safety and consistent progress.

During the interval when the work was suspended the shafts had filled with water and it was necessary to empty them out before resuming excavation. This was accomplished with comparatively little trouble by bailing and pumping. On March 3, 1909, excavation was again started in the east shaft, and on June 2, 1909, in the west shaft. The diamond drill chambers were first excavated, as before stated. These were of considerable size, large enough not only to permit the drills to be conveniently operated, but the drill rods to be removed and replaced in 30-ft. lengths. The chambers were excavated on inclines of about 45°, which added to the difficulty of the work, the incline being necessary to allow the rods to be pulled in the direction of the borings. On the completion of the chambers, shaft sinking was resumed and continued until the bottom was reached. The diamond drilling was not started until the shafts were approximately 50 ft. below the chamber, so as to insure the machines against injury

from blasting and also reduce the chance of the latter jarring the rock about the drill holes to the extent of blocking them. Large pump chambers of a size sufficient for three Jeanesville pumps (2 cylinder, 16 in. by 7 in. by 18 in.) were made in the sides as the shafts were sunk. These chambers are approximately at elevations −400 and −800, the idea being to pump in 400-ft. lifts, the bottoms of the shafts being assumed at elevation −1200, as before mentioned.

During the progress of the shaft sinking, the two pairs of inclined borings were completed and furnished data from which the elevation of the river tunnel could be fixed. The rule followed for other siphons of the aqueduct was to place the tunnel under a cover of sound rock at least 150 ft. thick. Following this rule, which was suggested by Senior Designing Engineer Wiggin, the elevation of the river tunnel was established approximately that distance below the elevation at which the upper pair of inclined borings crossed (about −955). It is not known what thickness of bedrock exists above this elevation and it was thought best to be conservative. The intrados of the concrete tunnel arch at the foot of the east shaft is to be at elevation −1100, and the corresponding point on the west side −1097. The drop of three feet is provided so that the water may drain to the sump at the east shaft when the siphon is unwatered in the future.

The shafts were sunk deep enough for, and the first rounds of holes were drilled for, the river headings on December 23, 1910, and February 13, 1911, in the east and west shafts respectively. After the tunnel from each shaft was driven 100 ft. or so, the pump chamber at the bottom and the deep permanent sump under the east shaft were excavated. The guides were then put in place for the cages and the latter were installed. The timbering of the shaft permitted room for only one cage in each shaft. Everything was then in readiness to proceed with the driving of the tunnel.

The west shaft is remarkably dry considering its depth below the drainage level of the country and its proximity to the river. About 30 gall. of water is pumped from it per minute. The east shaft is much wetter, however, the inflow amounting to 140 gal. per minute, most of which appears in the vicinity of the pump chamber at elevation −400.

When the shafts had reached their final depths and the headings were started at the elevations noted, it was considered that the exploration work was finished and it was deemed advisable to have the remaining work done by contract. Accordingly Contract 90, "For the Completion of the Hudson Siphon," was prepared and advertised, and on June 20, 1911, was awarded to the T. A. Gillespie Company, who began work on June 22, and who on September 6 had advanced the west heading a total distance of 853 ft. from the shaft. No advance has been made by them in the east heading for reasons to be stated. Taking both tunnels together, over one third of the total length of heading is now driven.

Contract 90 includes particularly the following: (1) The completion of the tunnel excavation under the river; (2) the lining of the tunnel with concrete to a finished diameter of 14 ft.; (3) the lining of the west shaft to the same diameter up to the land tunnel connection and the sealing and partial refilling of the shaft above it; (4) the lining of the east shaft to a finished diameter of 14 ft., with concrete guides for a cage and a pump float, and the furnishing and placing of the metal seal above the land connection; (5) a hydrostatic test of the shafts and tunnel if required; and (6) the construction of a drainage chamber over the east or pump shaft.

While this contract was being prepared and until the contractor took hold on the date named, the board's forces continued work and drove the headings from the east and west shafts a distance of 268 ft. and 218 ft. respectively. On April 21, 1911, when the east heading was at the distance named, a flow of water amounting to about 250 gal. per minute was encountered in firing the cut in the heading. At this time the large station pumps had not been installed in the bottom for fear the blasting would injure them, and it was necessary to fight the flow with the smaller pumps available for the purpose. Before the water was finally under control it had filled the tunnel to the roof, submerging some of the pumps. On May 5, however, the tunnel was emptied and three large station pumps have since been put in position to handle the water. A 4-in. pipe was inserted into the hole in the cut from which the flow came and was carefully braced and concreted in. The pipe was then continued to the shaft and up the latter 300 ft. to the pump chamber at elevation −800. After the

concrete in the plug had set, the valve in the T of the pipe near the heading was closed and the water rose by its own head to the chamber. This was, of course, a temporary expedient to get the water out of the way while arrangements were being made in the tunnel to handle it easily. The pipe will have to be taken away before the heading can be advanced. Under the requirements of Contract 90 the contractor is also preparing to install two electrically driven centrifugal pumping units, each of a capacity to discharge 500 gal. per minute from the bottom to the top of the shaft. With this outfit, should the equipment, either of centrifugal or reciprocating pumps, go out of commission temporarily, the other equipment can handle the water up to its capacity.

As an additional precaution the contractor has built, by direction, a heavy concrete bulkhead in the tunnel between the pumping station and the heading. This will be equipped with a cast-steel door swinging on hinges with the flow, which can be readily closed in the event of an accident to the pumps or of a sudden inflow of water that would overtax their capacity, thus preventing the drowning of the pumps while additional pumping units are being installed. The bulkhead and door are designed to withstand a hydrostatic pressure equal to the full depth below the river surface. The bulkhead is 14 ft. thick in the center and about 18 ft. at its contact with the rock of the tunnel.

Advantage has been taken of the delay incident to the installation of the pumping plant and the building of the bulkhead to put in an additional diamond drill hole in the face of the heading parallel with the axis of the tunnel. Although this hole was started only a few feet over the point in the face where the water-bearing seam was encountered, it had advanced on September 6 a distance of 468 ft. and flows only 32 gal. per minute, about half of which was encountered within 10 ft. of the face of the heading. This boring is made under a provision of Contract 90 and the work is being done for the contractor by Messrs. Sprague & Henwood, of Scranton, Pa., who drove so successfully the inclined holes from the shafts.

The flow of the water into the east heading was the subject of a number of sensational newspaper articles published soon after it was encountered. While it was no doubt the cause of some delay

to the work, it did not give rise to such alarm on the part of those on the work as casual readers of the newspapers would suppose. The amount of water, which now totals, with the flow in the shaft itself, to about 350 gal. per minute, is small when compared with that encountered in one of the headings of the pressure tunnel under the Rondout Valley, which amounted to 2 000 gal. per minute. This flow, diminishing gradually to 1 200 gal. per minute, has been pumped for many months past through a 500-ft. shaft to the surface. In spite of the interference with the progress which it caused, the tunnel has been successfully driven through the porous rock and is now in process of being lined with concrete.

It is interesting to note that analyses of samples of the water coming into the Hudson River tunnel through the seam mentioned show it to contain much more chlorine than samples of the river water taken at the same time, even at flood tide when the chlorine content of the river water is a maximum. For instance, samples taken from the river at low tide and from the tunnel on June 12, 1911, showed 14.5 parts and 4 150 parts of chlorine respectively per million. The tunnel water has been referred to by the geologists as " fossil " water that has been stored for ages in the seams far below the drainage level and below the zone of circulation.

The heading from the west shaft has been practically dry the entire distance of over 800 ft. A similar equipment of pumps, however, is to be installed there as in the east tunnel, and a concrete bulkhead built. The contract provides that " if ordered in any stretch of tunnel a test drill hole to be paid for " by the city " shall be carried about 10 ft. in advance of holes used for blasting." These holes, called " pilot holes," are intended to give warning, before blasting is done, of any water-bearing seam which may be in advance of the heading, and the precaution of drilling them is being followed regularly, though not always to the full depth of 10 ft. which may be required.

An interesting feature of the shaft sinking and tunnel driving is thus described by Messrs. Dodge and Hoke:

" A phenomenon which is peculiar and disconcerting to the workmen in the shafts is that of popping rock. Without warning there will be a loud report like a pistol shot, and a piece of rock from the wall will fly into or across the shaft. Usually the frag-

ment is small and does no damage, but at times has caused injuries of minor nature. This popping may occur from rock surfaces which have been uncovered several days. It has not been very frequent and was first noticed in the west shaft at elevation —450. Prof. W. O. Crosby has explained the phenomenon as an explosion resulting from the local relief from mechanical pressure to which the rock is subjected by the wedge-like structure of the granite underlying the river. He says:

"'The relief will normally find expression either in scaling or in the development of cracks or rifts, which, tending to be parallel with the east and west sides of the shafts, will rather seldom be subject to direct observation. Every such snapping or sudden giving way or rifting of the granite gives rise to a miniature earthquake.

"'I may add that this is a fairly common happening in mines and quarries. Often in quarries the compressive strain is measured by an appreciable stretching of the rock when released, so that it would be impossible to force a block into the space which it formerly occupied. This phenomenon of spontaneous snapping and rifting has recently been described as occurring in some of the deep Lake Superior copper mines.

"'That it was not observed nearer the surface in the Hudson River shafts is probably due to the relief long since afforded by the erosion of the gorge of the Hudson. It should not be regarded as jeopardizing appreciably the security of either shafts or tunnel, and it is evident that we have here a powerful agent tending to tighten and close up seams in the granite.'"

I cannot close this paper without calling attention to the very efficient service rendered by the division engineer, Mr. William E. Swift, in connection with the work described. He has been in direct charge of this particular problem from the inception of the work in 1905 until the present time. Under the chief engineer, Mr. J. Waldo Smith, it is due, in a large measure, to Mr. Swift's zeal and to his intelligent attention to the work that so many obstacles to success have been overcome and that the tunnel is so far advanced toward completion.

The designs for the pressure tunnel and its appurtenances were made by Mr. Thomas H. Wiggin, senior designing engineer, and his assistants, working under the direction of Mr. Alfred D. Flinn, engineer in charge of headquarters department, and of the chief engineer. The specifications for Contract 90 were prepared by headquarters department with the coöperation of Mr. Ralph N.

Wheeler, division engineer, Northern Aqueduct Department. The writer has had general supervision of the field work as engineer in charge of the latter department. He is indebted to Mr. Wheeler for much assistance in the preparation of this paper.

PROTECTION OF STEEL PIPES IN CATSKILL AQUEDUCT.

BY ALFRED D. FLINN, DEPARTMENT ENGINEER, BOARD OF WATER SUPPLY OF THE CITY OF NEW YORK.

[*Read September 14, 1911.*]

New York City's Catskill water system, final surveys for which were begun six years ago, is now so well known that even a brief outline is unnecessary as a foreword to this paper. In the 92 miles of 500-million-gallon aqueduct between Ashokan Reservoir and the city line there are numerous valleys to be crossed, varying in width from a few hundred feet to several miles. For fourteen of these depressions, steel-pipe siphons were determined upon as the most economical and otherwise suitable type of construction. Seven siphons are in the Northern Aqueduct department north of Croton watershed, and the remaining seven are in the Southern Aqueduct department; they are being constructed under two corresponding contracts: No. 62, with the Snare & Triest Company, and No. 68, with the T. A. Gillespie Company. West of the Hudson River there are three siphons, and east of the river, eleven.

To convey water to the full capacity of the other portions of the aqueduct, three pipes will ultimately be required, but since the city does not need the whole capacity for a number of years, only the middle pipe of each siphon is now being laid. Between Ashokan Reservoir and the Croton divide, the pipes are approximately 9 ft. in diameter; from the Croton divide to the connection for the proposed filter plant they are about 9.5 ft. in diameter; and from the latter point to Hill View Reservoir, 11 ft., for economical reasons, depending upon the available slope. Of course, the middle pipe alone will carry far more than one third the capacity of the three pipes all together,— the capacity of one pipe alone, when forced, being estimated at approximately 350 million gallons daily. At each end of each siphon is a concrete siphon chamber, forming the connection with the ad-

jacent cut-and-cover or tunnel portion of the aqueduct. In each chamber, sluice gates for controlling the flow of water into the several pipes will be installed. These chambers will have suitable superstructures; the chambers, but not their superstructures, are included in the contracts mentioned.

TABLE I.

Dimensions of Catskill Aqueduct Pipe Siphons.

NORTHERN AQUEDUCT DEPARTMENT.

Name of Siphon.	Length Feet.	Thickness of Plate, Inches, and Kind of Joint.	Maximum Head, Feet.	Diameter of Pipe Shell.	Finished Diam. of Siphon.
West of Hudson River.					
Esopus	2,110	$\frac{7}{16}$; lap.	107	9 ft. 6 in.	9 ft. 2 in.
Tongore	643	$\frac{7}{16}$; lap.	72	9 ft. 6 in.	9 ft. 2 in.
	53	$\frac{9}{16}$; long. seams butt-jointed.			
Total	696				
Washington Square,	3,281	$\frac{7}{16}$; lap.	90	9 ft. 6 in.	9 ft. 2 in.
East of Hudson River.					
Foundry Brook	3,490	$\frac{7}{16}$; lap.	192		
	288	$\frac{1}{2}$; lap.		9 ft. 6 in.	9 ft. 2 in.
Total	3,778				
Indian Brook	608	$\frac{7}{16}$; lap.	70	9 ft. 6 in.	9 ft. 2 in.
Sprout Brook	1,061	$\frac{7}{16}$; lap.	234	9 ft. 6 in.	9 ft. 2 in.
	119	$\frac{1}{2}$; lap.			
	1,044	$\frac{1}{2}$; long. seams butt-jointed.			
Total	2,224				
Peekskill	2,162	$\frac{7}{16}$; lap.	340	9 ft. 6 in.	9 ft. 2 in.
	218	$\frac{1}{2}$; lap.			
	1,251	$\frac{1}{2}$; long. seams butt-jointed.			
	1,876	$\frac{9}{16}$; long. seams butt-jointed.			
	1,025	$\frac{11}{16}$; long. seams butt-jointed.			
	139	$\frac{3}{4}$; long. seams butt-jointed.			
Total	6,671				

PLATE I.
N. E. W. W. ASSOCIATION,
SEPTEMBER, 1911.
FLINN ON
PROTECTION OF STEEL PIPE.

FOUNDRY BROOK SIPHON.

Whitewashed 9 ft. 6 in. pipes; finished earth trench with one type of concrete cradles in foreground.

TABLE 1.—*Continued.*

SOUTHERN AQUEDUCT DEPARTMENT.

Name of Siphon.	Length Feet.	Thickness of Plate, Inches, and kind of Joint.	Maximum Head, Feet.	Diameter of Pipe Shell.	Finished Diam. of Siphon.
Hunters Brook	1,493	$\frac{7}{16}$; lap.	110	9 ft. 9 in.	9 ft. 5 in.
Turkey Mountain..	1,510	$\frac{7}{16}$; lap.	92	9 ft. 9 in.	9 ft. 5 in.
Harlem Railroad...	694	$\frac{7}{16}$; lap.	60	9 ft. 9 in.	9 ft. 5 in.
Kensico	1,625	$\frac{7}{16}$; lap.	50	9 ft. 9 in.	9 ft. 5 in.
Elmsford..........	1,490	$\frac{7}{16}$; lap.	68	11 ft. 3 in.	10 ft. 11 in.
Fort Hill..........	1,267	$\frac{7}{16}$; lap.	72	11 ft. 3 in.	10 ft. 11 in.
Bryn Mawr.......	2,714	$\frac{7}{16}$; lap.	214	11 ft. 3 in.	10 ft. 11 in.
	150	$\frac{1}{2}$; lap.			
	2,465	$\frac{1}{2}$; long. seams butt-jointed.			
	255	$\frac{9}{16}$; long. seams butt-jointed.			
TOTAL........	5,584				

Total length of all siphons, 33,031 ft.

Efficiency of single-riveted lap joints, about 50 per cent.; double-riveted lap joints, 70 per cent., and of triple-riveted butt joints, 81 per cent.

Having settled upon metal pipes, the next most important phase of the problem was to make these siphons as nearly as feasible comparable in durability to the masonry types of aqueduct. Attention was directed first to finding a pipe metal less corrodible than steel. Such evidence as was at hand and could be collected within the time at our disposal, pointed to genuine wrought iron as being possibly superior in this respect to other metals. Investigation, however, disclosed the facts that wrought iron could not be obtained in sufficiently large sheets, and its strength would be less, hence the thicknesses of the pipes would be greater, leading to greater cost. Cost would not have been a controlling factor if satisfactory assurance of accomplishing the desired result had accompanied increased expenditure. Deliveries, furthermore, would probably have been too slow for the necessary progress in construction. Consequently, it was decided to use the best available quality of steel.

Steel having been selected as the metal for the pipe plates, attention was directed to the best method of protecting it. Reports of experience from many places and special examinations

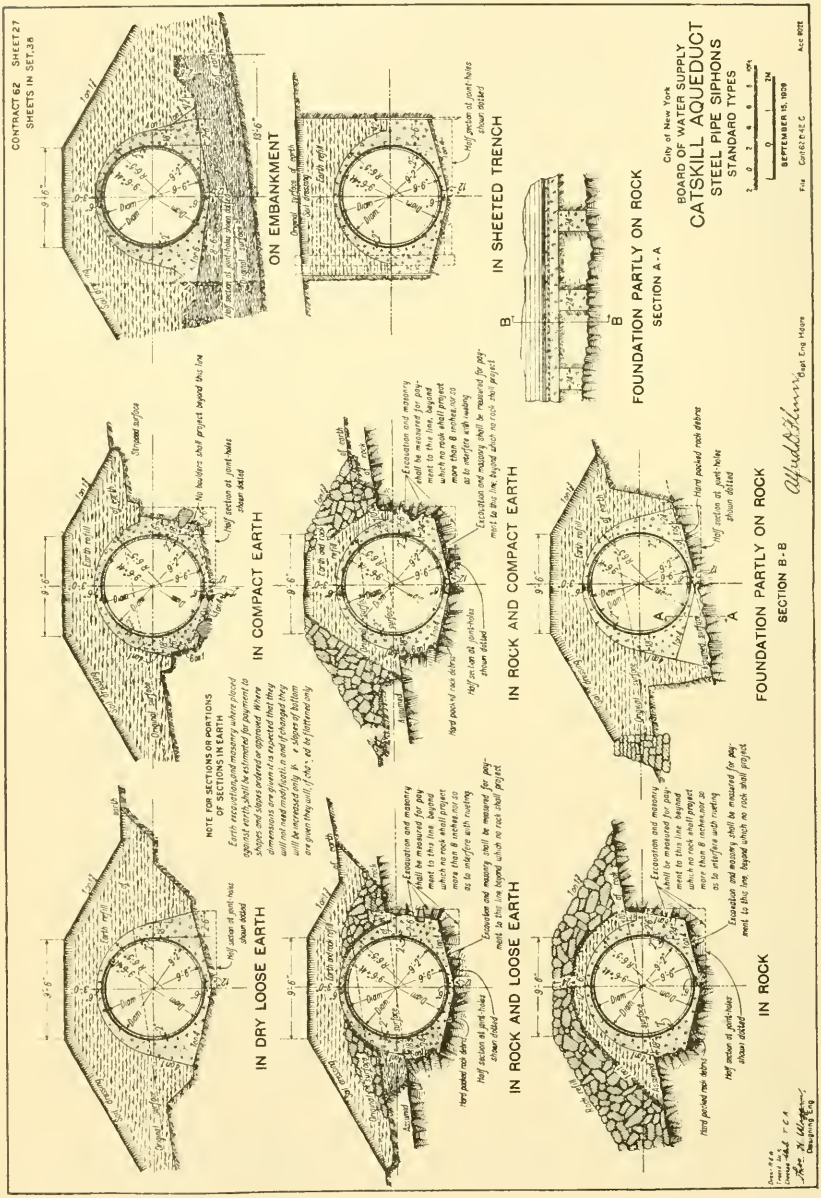


Fig. 1.

Standard Types of Trench, Embankment, and Jacket, similar for all sizes of pipe.

of many steel pipe lines of varying ages gave convincing proofs that none of the pipe coatings commonly used was possessed of qualities giving it more than a few years' useful life, with our waters and soils. One or two cases of use of Portland cement mortar on a small scale in pipes, and wide experience in reinforced concrete construction, of the protective action of Portland cement on steel, pointed to a method for coating the pipes. After some study it was decided to jacket the steel siphons of the aqueduct outside with rich concrete mixed about one part of cement to three parts sand and six parts broken stone or gravel, with a minimum thickness of 6 in., and to line them with Portland cement mortar, 2 in. thick at the minimum. Standard cross sections of the pipes are shown in Fig. 1.

Methods of applying the concrete and mortar next received consideration. Improvements for attaining intimate, complete, and permanent adhesion in spite of the unavoidable changes in shape and the elastic distortions of the pipes were sought, along with the most economical and practicable methods for the various steps in covering and lining. Preparation of the steel to receive concrete and mortar was also carefully studied. Numerous experiments were conducted especially on placing the lining.

Mortar lining experiments were made at nearly full size. A steel pipe 9 ft. in diameter and 12 ft. long, of $\frac{3}{8}$ in. riveted plates, was lined by plastering with metal reinforcement of several styles, by plastering with terra cotta and cement blocks or tiles, and by pouring grout or very thin mortar into the space between a cylindrical steel form and the interior surface of the pipe. To summarize the results briefly, no combination of plasterer's skill with various kinds of Portland cement mortar, reinforced or unreinforced, gave linings that were adequate, and this method was expensive. Bedding tiles of terra cotta or mortar about $\frac{3}{4}$ to $\frac{7}{8}$ in. thick and 6 by 8, 6 by 12, and 8 by 12 in. on mortar applied directly to the pipe surface, and, after setting, building up the lining to the required thickness with successive coats of mortar troweled on was much more satisfactory, but was also expensive. The grouting method proved by far the most satisfactory and least expensive and was made the basis of the specifications. With proper regard for certain details, this last method gave promise of being feasible

in actual construction. It also had the advantage of producing a monolithic lining, which was considered desirable, especially in the avoidance of layers, or lamina, in the thickness, since it is well known to be difficult to cause one layer of Portland cement mortar or concrete to adhere absolutely and permanently to another without expensive and troublesome precautions. As the successive experimental linings were removed from the test pipe it was observed quite generally that linings applied in layers separated.

As the result of these studies and experiments, the following specifications were written:

Extracts from Contract 62.

GENERAL SECTIONS.

Order of Work.

Sect. 19. The steel pipe shall be laid, tested, and made tight against hydrostatic pressure; then surrounded by concrete while still under the normal hydrostatic pressure, after which the mortar lining shall be placed. Except at overhead stream crossings, no stretch of pipe shall be left not well protected from frost between stretches of pipe around which concrete has been placed. As soon as practicable after the concrete covering and mortar lining have been placed, the pipe shall be covered with earth; and all pipe covered with concrete, whether or not mortar lining has been placed in it, shall be protected in freezing weather by at least one foot of earth.

$9\frac{1}{2}$-FOOT STEEL PIPE.

(Items 19 to 24.)

Work Included.

Sect. 19.1. Under Items 19 to 24 inclusive, the contractor shall furnish and lay, test, and make tight the 9-ft. 6-in. steel pipe between the siphon chambers at each siphon. The pipes will vary in thickness according to depth below the hydraulic gradient of the aqueduct, and are grouped in the six items according to thickness, irrespective of location.

Material.

Sect. 19.2. Steel for plates and rivets shall be made by the basic open-hearth process. Steel for plates shall fulfill the requirements for " flange steel " and rivets for " extra soft steel " as given

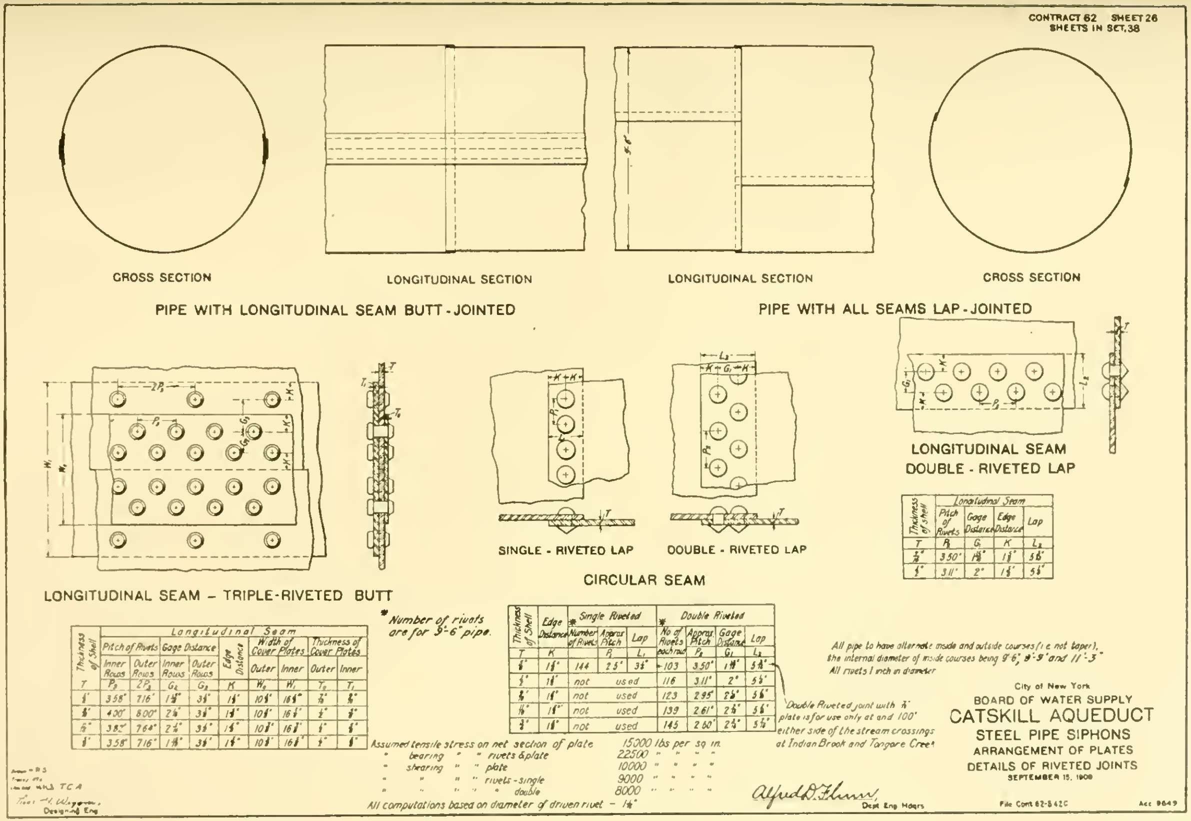


Fig. 2.

Standard Joint and Rivet Details, similar for all sizes of pipe.

in the Standard Specification for Open-Hearth Boiler Plate and Rivet Steel, adopted August 16, 1909, by the American Society for Testing Materials. All specimens and records shall be furnished and analyses and tests made as therein provided. The engineer shall be informed in advance of all times of sampling and testing and be permitted to witness such of these operations as he desires. Duplicate samples shall be furnished to the engineer whenever required.

Dimensions.

Sect. 19.3. The pipes shall be made with alternate inside and outside courses, and the designated diameter of 9 ft. 6 in. shall be measured as the inside of the inside course. The lengths of the courses, unless otherwise permitted, shall be 7 ft. 6 in. center to center of circular joints on regular straight pipe, and on the long side of courses cut or beveled to form angles or curves. Each course shall be formed of not more than two plates.

The plates used and the design of joints shall be as given in the table on Sheet 26 [Fig. 2] of the drawings. Slight variations from the dimensions given will be allowed provided they do not, in the opinion of the engineer, affect the strength of the joint.

Shaping and Rolling Plates.

Sect. 19.4. The plates shall be rolled to true cylinders while cold. No heating nor hammering shall be allowed for shaping or curving, nor for any other purpose. All parts shall be adjusted to a perfect fit and properly marked.

Other than Riveted Joints Permitted.

Sect. 19.5. Joints formed by welding or by special devices, giving strength equal to or greater than that of the riveted joint specified above, will be allowed on proof of efficiency and lasting qualities satisfactory to the engineer, but no reduction in thickness of plate will be considered.

Planing and Calking.

Sect. 19.6. The edges of plates that are $\frac{1}{2}$ in. or more thick shall be planed. Lap joints shall be calked all around, both inside and outside, and butt joints shall be calked outside only. At the end of each course and at the junction of the circular and longitudinal seams, the plates shall be reduced by hammering to a fine edge, through which two rivets of the circular seam shall be driven to insure tightness.

Rivet Holes.

SECT. 19.7. The work shall be carefully and accurately laid out and all rivet holes shall be spaced with precision. Holes in $\frac{1}{2}$-in. and thicker plates shall be drilled from the solid or punched to an approved size and reamed. Punched holes shall be clean cut, without torn or ragged edges, and in punching only the best and sharpest punches and dies shall be used. The engineer shall have the right to order a change of punch or die whenever the holes are not punched to his satisfaction. All burrs or splits caused by punching shall be removed by counter-sinking.

Holes Not Drifted.

SECT. 19.8. Corresponding holes shall, without enlarging, coincide to within about $\frac{1}{32}$ in., and all plates in which corresponding holes do not so coincide shall be rejected, unless the engineer shall be of the opinion that the conditions of stress are such at the point in question as to make a more extensive enlargement safe. Drift pins shall not be used in forcing holes, but any perceptible lack of coincidence in acceptable plates shall be corrected by a sharp reamer or drill.

Riveting.

SECT. 19.9. All riveting in longitudinal seams shall be done by hydraulic, compressed air or steam machinery, exerting a pressure on each rivet sufficient to produce the best results. This pressure shall be retained until the rivet head has been perfectly formed and the metal has lost its red color. Before any rivets are driven, the plates shall be brought into close contact by a suitably applied pressure, which shall be maintained until the rivets are driven. All rivets shall be driven at such heat as to give the best possible results. Any rivet that is in any way defective shall be cut out and replaced by one that is acceptable. All rivets shall be perfect in form; when driven they shall completely fill the holes and have heads of proper form and size, free from checks and cracks, and truly concentric with the shank. Rivets of extra length shall be used when riveting through more than two thicknesses, and in all places where castings or flanges of any description are to be attached to the pipe. All rivet heads inside the pipe on the butt strap of the smaller rings of pipe shall be of an approved flattened shape, substantially as shown on Sheet 6; all rivets may be so made, if desired.

Samples of Riveting.

In order to prove the sufficiency of proposed rivet driving pressures and of methods and apparatus for both shop and field

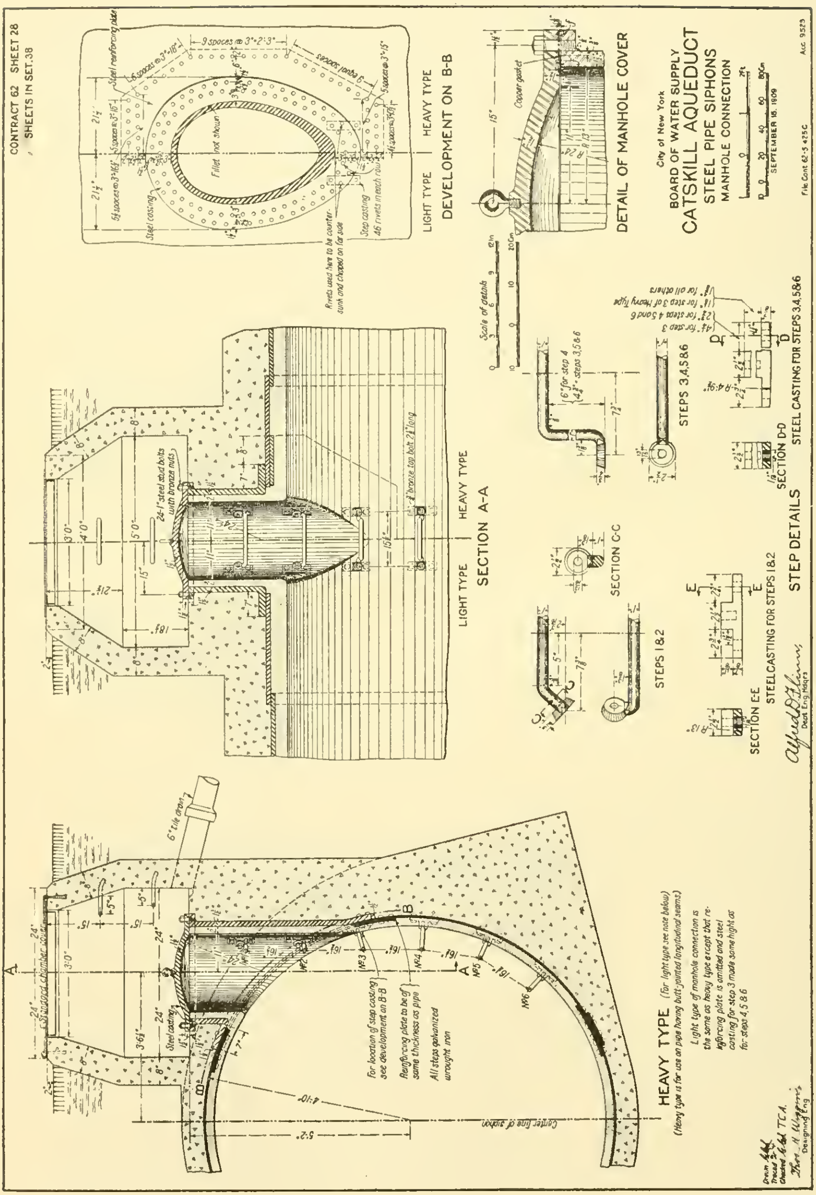


FIG. 3.

STANDARD MANHOLES FOR STEEL PIPE SIPHONS.

joints, the contractor shall supply, as directed, samples of each kind of joint and riveting both in thin and in thick plates. These samples will be from 5 in. to 10 in. wide and 12 in. to 30 in. long after fabrication. Not over fifteen samples will be required unless the results of any test indicate unsatisfactory methods, in which case such tests shall be repeated until satisfactory methods are used.

Testing Samples.

The contractor shall do such sawing as required through plates and rivets, to show the degree of closeness with which the rivets fill the holes. Labor and materials required to furnish and test these samples, as above specified, will not be estimated for payment, but compensation therefor will be considered as included in the prices stipulated for the various items of steel pipe.

Connections.

SECT. 19.10. Manhole, blow-off, and drain castings paid for under Item 25 are to be attached to the pipe as shown on Sheets 28 [Fig. 3], 30 [Fig. 4], and 33 [Fig. 5]; the pipe is to be reinforced at certain manholes and at all ends entering the castings at siphon chambers. An air-valve is to be connected to the pipe at Peekskill siphon and one at Foundry Brook siphon, the reinforcement of the plate and cutting and threading of the hole being included in these items. All cutting, punching, riveting, calking, and other work necessitated by these connections shall be included in the prices stipulated for these items and for Item 25 (steel castings).

Hand and Grout Holes.

SECT. 19.11. Holes tapped for 2-in. pipe, for introducing hot rivets, and for grouting shall be provided in the top of the pipe as nearly as practicable at the uphill end of each outside course, in order to prevent air pockets during grouting. Additional holes shall be placed as required at curves, where lining is to be built in short lengths. These openings in $\frac{7}{16}$-in. and $\frac{1}{2}$-in. plates shall be reinforced by a plate riveted on, or in some other approved manner, and shall be closed after grouting by threaded plugs, so as to be water-tight.

Curves.

SECT. 19.12 Wherever changes in line or grade of the pipe make angles necessary, they shall be formed by cutting and beveling the ends of a sufficient number of courses to produce the desired total deflection or curvature.

Stopping Leaks; Rivet Calking.

SECT. 19.13. All leaks shall be stopped by suitable calking with the proper tools. Rivet calking shall not be allowed if the rivet is loose, nor unless the leak is very slight and easily closed. Otherwise the rivet shall be cut out carefully and a new one inserted and headed up tight while hot. If the leaks are numerous and of a nature not to be well repaired, the whole section shall be rejected.

Transportation.

SECT. 19.14. During transportation and in loading and unloading the pipes, more than ordinary care shall be taken to prevent injury, and such work shall be done slowly, with the pipe at all times under perfect control, and under no conditions shall a pipe be dropped. In distributing the pipes in the field, each piece shall be placed as near as possible to the point where it is to be laid and faced in the proper direction. Suitable skids or blocks shall be left under each pipe, which shall be securely wedged to prevent movement until the pipe is required. In case any pipe receives any indentation or deformation, it shall be returned to the proper shape by satisfactory methods, if such repairs are acceptable; otherwise, it shall be replaced with a new pipe at the expense of the contractor.

Laying Pipe.

SECT. 19.15. The pipe shall be laid accurately to line and grade. It shall be supported either by suitable temporary blocking and wedges or by other approved means, at a sufficient number of points to prevent deformation when filled with water during testing and concreting. If blocking be used, it shall be removed as the concrete work progresses, care being taken to prevent settlement of the pipe.

Field Testing.

SECT. 19.16. When the steel shell at any siphon, or a sufficient length of it, is completed, it shall be tested with water under pressure corresponding to the hydraulic gradient of the aqueduct at this point, and all leaks shall be calked and made tight. The contractor shall furnish the clean water, bulkheads, connections, and all apparatus necessary, and shall be responsible for any damage resulting from the test.

Pipe Held Full during Covering.

Water at full pressure shall be kept in the pipe during the placing of the concrete covering and until the concrete last placed shall

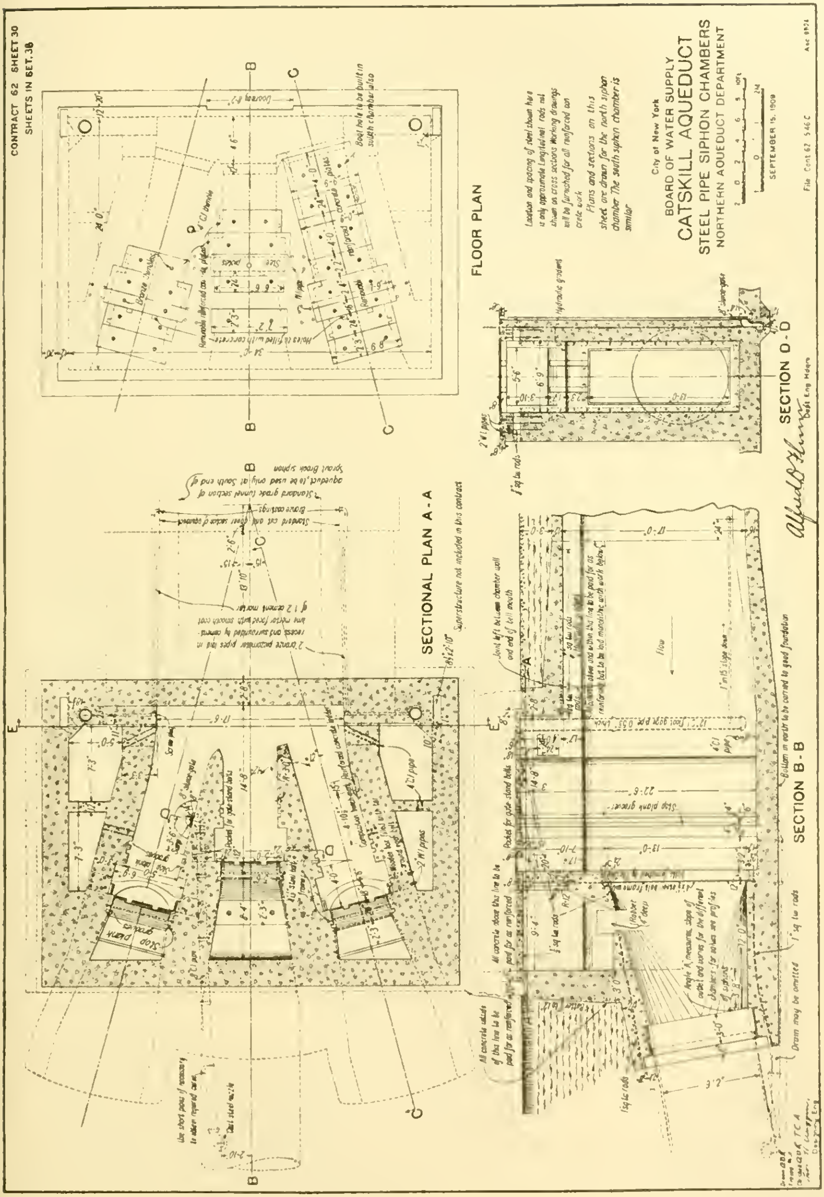


FIG. 4.

STANDARD SIPHON CHAMBER. ONE AT EACH END OF EACH SIPHON EXCEPT SOUTHERLY END OF BRYN MAWR SIPHON.

have set for at least forty-eight hours. The contractor shall then free the pipe from water.

Cleaning and Protection from Rust.

SECT. 19.17. During fabrication into pipe, all steel plates, at each joint where one plate covers another, shall be entirely free from mill scale, from any but light rust, and from all dirt, grease, or other foreign matter. Furthermore, when concrete is placed around, or mortar lining placed within, any section of pipe, the surface of the plate shall be similarly clean. The degree of cleanliness and freedom from scale required shall be such as produced by thorough sand-blasting or thorough pickling; i. e., such that the surface of the steel itself is exposed. The initial cleaning may be done at the mill provided the steel is adequately protected and necessary field cleaning is done. The exposed surface of pipe at the overhead stream crossings at Tongore, Foundry Brook, and Indian Brook siphons shall be given three coats of approved paint, applied to metal cleaned as above specified. Two of the coats shall be applied after erection.

Measurement and Payment.

SECT. 19.18. The quantity to be paid for under each of the items 19 to 24 inclusive shall be the total number of linear feet of $9\frac{1}{2}$-ft. steel pipe shell laid, measured along the axis of the pipe line after laying. The price shall cover all labor and materials necessary to furnish and lay the steel pipe shell, do all cleaning and testing, perform all work on connections not specifically included in Item 25, and complete the pipe in the manner specified.

MORTAR LINING FOR STEEL PIPES.

(Item 26.)

Work Included.

SECT. 26.1. Under Item 26 the contractor shall build a mortar lining inside the steel pipe and cast-iron bell castings as specified, directed or approved.

Description and Proportions.

SECT. 26.2. The lining shall consist of Portland cement and sand, mixed in ordered proportions, probably one part of cement to two parts of sand. The quality of the sand shall be as specified under Items 28 to 30. Reinforcement, if used, will be paid for under Item 27. The lining shall be of substantially uniform thickness throughout the entire circumference except for the un-

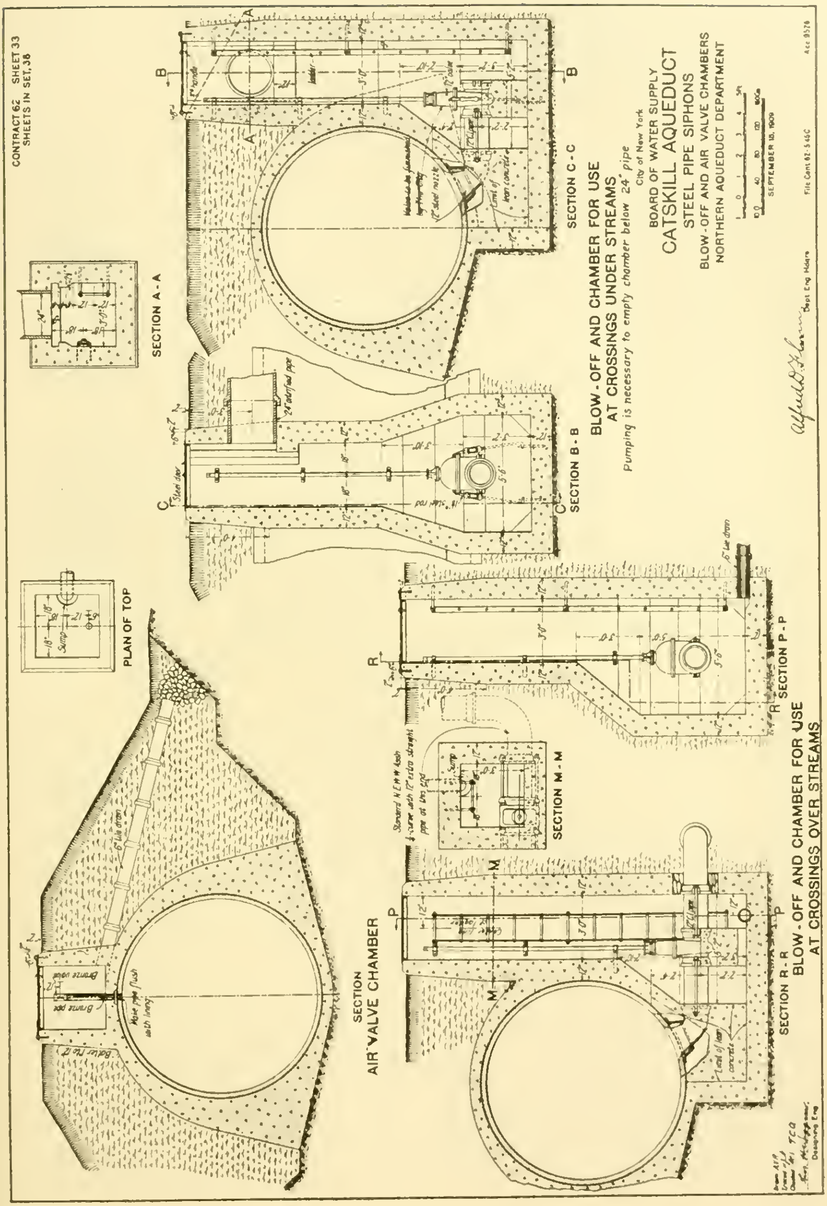


FIG. 5.

STANDARD BLOW-OFFS AND AIR VALVE CHAMBERS.

avoidable variations due to lap of the plates, butt straps, and rivet heads. The thickness over the inner course of plates is to be 2 in., that is, the internal diameter of the lining shall be four inches less than the nominal diameter of the steel shell.

Forms.

SECT. 26.3. Forms shall be of steel, or of wood covered with galvanized sheet steel, and shall be especially constructed so as to have sufficient strength and yet be adjustable so as to give a uniform space between them and the shell of the pipe. Great care shall be exercised to secure forms which will leave the surface of the lining perfectly smooth. Forms which give unsatisfactory results after use shall be satisfactorily repaired or replaced. The length of the sections of forms will not be restricted provided satisfactory means are adopted for controlling the uniform thickness of the lining and the correct spacing of the reinforcement, but sufficient sections shall be provided adapted for lining the pipe on curves, where lining shall be placed in sections about 7 ft. long. Each time the forms are used they shall be thoroughly cleaned and then coated with some approved inadhesive substance which will prevent the mortar from sticking to the forms without injuring the mortar. The lining of manhole castings, and of the blow-off elbows to the sockets, shall be monolithic with the lining of the steel shell, and forms shall be so constructed as to permit this method.

Method of Placing.

SECT. 26.4. The lining shall in general be placed by pouring as grout around an internal form, through holes cut in the top of the pipe for that purpose in the manner and at locations specified in Section 19.11. Sections shall be so terminated as to bring a hole at the upper end which shall be arranged as an air vent. The mortar shall be mixed to a thick creamy consistency and allowed to flow into place as uniformly as possible. When the section is filled to the top, the pouring of the grout shall be continued until grout runs from the air vent; then headers of steel pipe shall be screwed into the inlet and outlet holes and filled with grout so as to put a head of at least 4 ft. on the highest part of the section, and these headers shall be kept filled with grout until the grout has set, when the pipe shall be removed and the hole made water-tight by a screw plug. During the pouring of the grout, the form shall be tapped to loosen air bubbles, and a careful watch shall be maintained to prevent leaks. The work shall be so planned that the grout can be poured continuously from start to finish of the section. Any interruption greater than

fifteen minutes, whether due to leaks or any other cause, may be sufficient reason for the rejection of the entire section.

Lining with Plaster.

SECT. 26.5. Should there by any portion of the interior of the pipe which it is impracticable to line by grouting, this portion shall be lined by plastering the pipe with mortar, mixed as specified in Section 26.2. Only skilled masons or plasterers shall be allowed to do this plastering, and a section once started shall be prosecuted until finished, with only such pauses as are necessary for a sufficient setting of a layer to permit the next layer to be placed. Each layer shall be as thick as is feasible to apply, so that as few layers as possible may be necessary. The surface of each layer, except the final one, shall be brushed to thoroughly remove the laitance and then deeply scratched or otherwise satisfactorily treated to give a bond with the succeeding layer.

Removal of Forms.

SECT. 26.6. The forms shall be removed within twelve hours of the time set by the engineer, and the section, if accepted, shall receive immediately such repairs as required, in the manner directed. It is possible that the lower part of the lining will, in many cases, show a sandy surface, and if so, it shall be brushed with enough neat cement wash to fill the pores and no more, and troweled to a smooth finish. Any section not accepted shall be immediately removed by the contractor at his own expense and replaced by acceptable lining.

Prevention of Freezing; Bulkheads.

SECT. 26.7. Suitable bulkheads shall be erected in the pipe to prevent freezing inside the pipe either during the placing of the lining or after its completion. They shall be removed before the completion of the contract, if ordered. Lining shall not be placed in the uncovered pipes over streams during, or within a month before, freezing weather, unless the pipe is satisfactorily protected, and, after lining these portions of the pipe, water shall not be allowed to stand and freeze there.

Measurement and Payment.

SECT. 26.8. For placing the lining in the steel pipe and cast-iron bell castings, the contractor shall receive the price per linear foot of pipe stipulated, the measurement to be made along the axis of the pipe, this price to include all labor and materials necessary to complete the lining in a thorough and approved manner except only that the cement required will be paid for under Item 35 (Portland cement).

REINFORCEMENT OF MORTAR LINING FOR STEEL PIPES.

(Item 27.)

Description.

SECT. 27.1. Reinforcement may be ordered under Item 27 for any part or the whole of the mortar lining. The reinforcing material shall be galvanized steel mesh of a style and weight approved, provided, however, that no reinforcement shall be required of which the lowest price obtainable by the contractor, f.o.b. New York City, exceeds $\frac{3}{4}$ cent per square foot, for lots of 10 000 sq. ft.

Placing.

SECT. 27.2. The reinforcement shall be placed approximately in the center of the mortar lining. The reinforcement may be kept away from the pipe by distorting the reinforcement at frequent intervals, so as to make points projecting toward the pipe. Unless otherwise permitted, small blocks of mortar shall be attached to the reinforcement, for the purpose of keeping it away from the form. Metal shall be lapped at least 6 in. at all longitudinal joints.

Measurement and Payment.

SECT. 27.3. The quantity to be paid for under Item 27 shall be the number of square feet of lining, measured as of a mean diameter 9 ft. 4 in., in which reinforcement has been ordered and placed. This does not include any allowance for lap. The price stipulated shall include the cost of the reinforcing metal, royalty if any, cutting, shaping, bending, wires, clips, mortar, and other devices used for holding the reinforcement in place, or for splicing the strips; and it shall further include any additional expense of forms, tools, appliances, and labor other than the expense that would be required for finishing the mortar lining under Item 26 without reinforcement.

All drawings reproduced as illustrations are for the 9-ft. 6-in. pipes. Corresponding drawings for the other sizes are similar; likewise standard dimensions for rivet and joint details.

All pipes for both contracts were fabricated by the East Jersey Pipe Company, Paterson, N. J., from plates rolled at the Carnegie steel mills near Pittsburgh. After the plates had been bevel-planed on their edges and punched for the rivets, each was bent to proper radius by rolls. This latter operation cracked the mill scale and

loosened it pretty thoroughly, incidentally removing a considerable portion; to remove the remaining mill scale, the rust, and the dirt, the plates were then dipped vertically in a wooden tank containing hot dilute sulphuric acid. This pickling solution was kept at a strength of about 5 per cent. of oil of vitriol, which was approximately 93 per cent. pure sulphuric acid. This bath was maintained at a temperature near 125° fahr., and each plate was in it about fifteen minutes. When removed, the plates were of a uniform, clear steel gray all over, and were at once dipped in clean hot water in an adjacent tank to remove all acid. Fitting and riveting followed promptly. The pipes were made in 15-ft. sections, each of two rings of 7.5 ft. net length. Each ring was of one plate, excepting in the 11-ft. 3-in. pipes, and in pipes made of plates thicker than $\frac{1}{2}$ in., for which two plates were necessary.

As a partial protection against rusting between the times of fabrication and of applying the concrete and mortar, each pipe was given a coat of heavy lime whitewash, made as follows: To one barrel of whitewash (about 50 gallons) there were added 20 pounds of glue; after using this whitewash for a time, about one pound of Portland cement was added for each gallon of whitewash; the glue was dissolved in water before being mixed in the whitewash.

This whitewash was applied with brushes. A spraying machine operated by compressed air was tried but found unsatisfactory. The whitewash did not adhere very well, and, through lack of care in handling the pipes, suffered more or less almost as soon as applied. This temporary coating, however, did not suffer from abrasion or cracking off so much as from exposure to the weather, and even where the whitewash was not disturbed, light rusting occurred. The only places where there was no sign of rusting was around the rivets and at joints, where the whitewash had formed a very thick coating. Consequently, the pipes arrived at the trench with more or less complete coats of light yellow rust; this rust was very uniform on the bared portions of the steel surface, without indications of any tendency to pitting, and has been regarded as unobjectionable.

Delays in laying some of the pipes and further delays in covering them with concrete are permitting the gradual formation of heavier rust, which is being removed, as required by the specifications.

Any remaining whitewash is also removed before applying the concrete or mortar. Ease of removal and absence of serious effects upon the concrete or mortar, if small quantities should not be removed, were among the principal reasons for adopting lime whitewash. Portland cement grout would have adhered more tenaciously, but difficulty of ultimate removal and its probable interference with the good adhesion of the final concrete and mortar coatings were sufficient arguments for forbidding its use. There is room for improvement in this step of our process for protecting steel pipes. Final field cleaning is done in short stretches just in advance of placing the concrete or mortar. Commonly wire brushes alone are used, but for some of the worst places steel scrapers also are employed. Inside some of the siphons the surfaces of the plates have been rubbed with empty cement bags after the wire-brushing.

After the bottom of the trench has been shaped, concrete cradles are built in it to support the pipes so that the invert of the jacket can be placed underneath. Where the trench is in soft ground, cradles have been carried down to good foundation. Their tops are grooved to aid in grouting to insure complete contact of the cement protection with the pipe. In the illustrations a number of these cradles are shown. The size and shape of invert cradles used to date in the Northern Aqueduct Department have varied considerably. The contractor's first choice was for a block 4 ft. wide (transverse to the pipe axis) and 3 ft. long (parallel to the pipe axis). This block was cast using forms with a top radius approximately equal to the pipe radius and of a thickness equal to the normal contract requirements. Trouble was experienced in getting so long a block true to the pipe radius and profile, also with breakage. The contractor next suggested a block 6 ft. wide and 2 ft. long, curved to the pipe radius. This was used only a short time and was then modified by flattening the ends for approximately 1 ft., leaving about 4 ft. of cradle in contact with the pipe (Fig. 6). Some trouble was experienced also in getting this block true to grade, and frequent breakages occurred. Early this season a few cradles were made about 24 in. square and carried 6 in. below the ordinary subgrade of the trench. These cradles were laid to pipe grade and have on the whole been satisfactory. Breakages and chipping of

PLATE II.
N. E. W. W. ASSOCIATION,
SEPTEMBER, 1911.
FLINN ON
PROTECTION OF STEEL PIPE.

BRYN MAWR SIPHON.

Rock trench; concrete cradles, showing forms in foreground.

edges have been less, and on account of the greater depth there has been little trouble with undermining. The forms for this type of block are also more easily set. Forms have consisted of light lumber sections and have been set true to line and grade, alternate blocks being set slightly lower to accommodate the outside rings of the pipe. The spacing of the square blocks has been symmetrical with respect to transverse joints, one block under each ring.

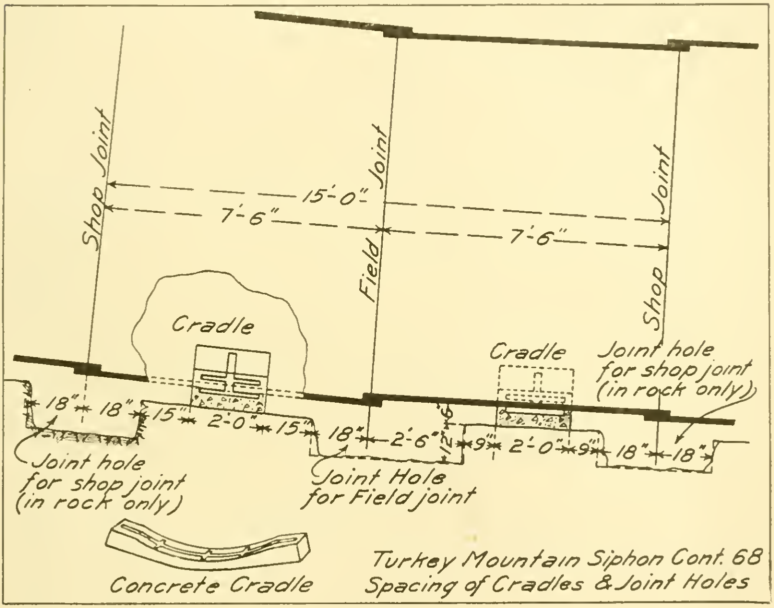


Fig. 6.

Typical Arrangement of Concrete Cradles and Joint Holes for Field Riveting.

With the other blocks one has been used under each ring, but so spaced as to give 3 ft. to 3 ft. 6 in. calking space in front of the field joints. This is an important detail where wide blocks are used.

In the Southern Aqueduct Department in all cases two cradles have been built under each 15-ft. section of pipe. The size, shape,

and placing of cradles has varied at the different siphons. At three siphons the cradles were constructed with their bearing surfaces molded to the theoretical radius of the steel pipe. At Fort Hill siphon (Fig. 7) the cradle under the inside ring is located with its face 3 ft. 6 in. from the field joint, this cradle being 2 ft. wide and having a bearing surface 6 ft. long molded to the theoretical curvature of the pipe. The cradle under the outside ring is located 2.5 ft. from the field joint, being 3 ft. wide, with the same bearing surface as the one under the inside ring. At Elmsford siphon (Fig. 7) both cradles were made 3 ft. in width, the one under the inside ring being located 2.5 ft. from the field joint, that under the outside ring 2 ft. 3 in. from the field joint. These cradles have a bearing surface of 6 ft., the curvature being somewhat flatter than the theoretical curvature of the steel pipe. A considerable number of cradles have cracked transversely during the process of laying or after the pipe has been placed. Some of these cracks have been caused by the handling of the pipe on the cradles during the process of laying; other cracks have occurred in the sand cuts, due in some cases, probably, to a slight settlement of the cradles, caused by excavation for joint holes, and in other cases, on steep slopes, cracks have been caused by settlement of cradles due to erosion. It is probable that most of these cracks are due primarily to the uneven bearing of the pipe on the cradles.

After the laying and riveting in the ditch have been completed, the pipe is filled with water to hydraulic gradient, inspected, and leaks calked. For this purpose — since the siphon chambers have not been built in time — bulkheads have been placed in the open ends of the pipe and a small riser pipe carried up to the proper elevation, and water kept just spilling over the top of this small pipe or of a small tank. Hydrostatic pressure should be maintained by a small reservoir, with controlled overflow, and not by direct pumping into the steel pipe during the placing and hardening of the concrete jacket. Fluctuations of the head or pulsations due to pumping have caused cracks. While still full of water under normal working pressure, the steel pipe is jacketed with concrete, and this pressure is continued until the concrete has attained considerable strength, or for not less than about two days after the placing of the last concrete, depending upon weather, kind of cement,

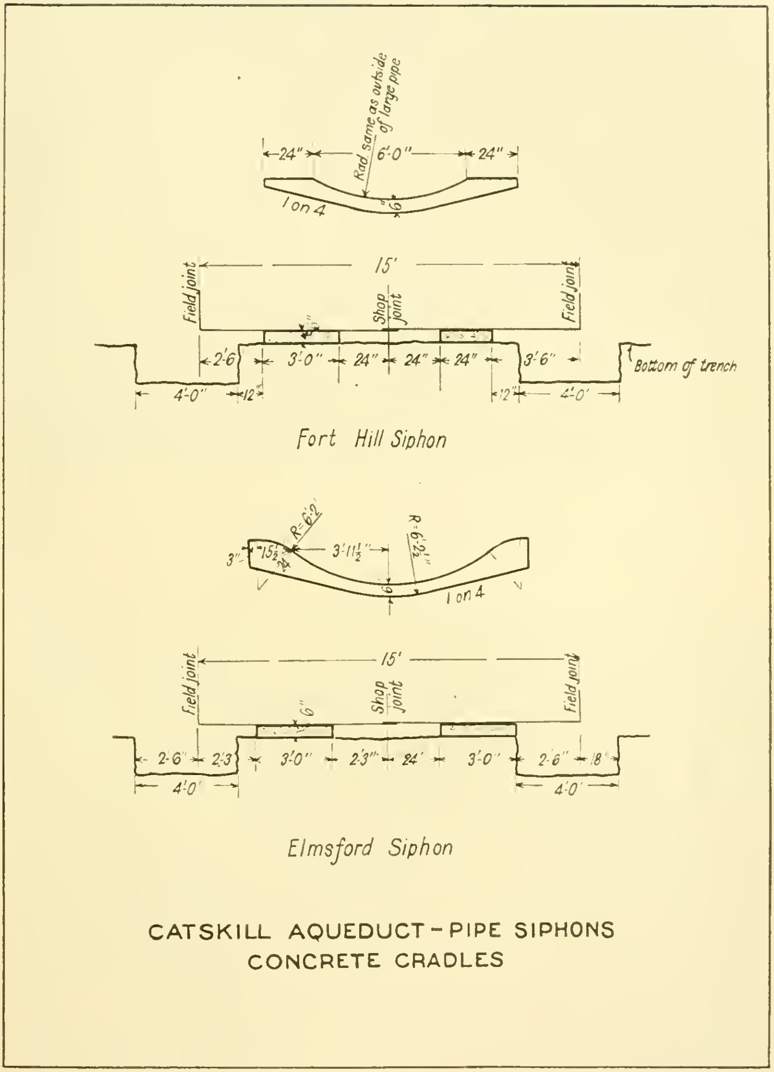

Rad. same as outside of large pipe
24"
6'-0"
24"
1 on 4
15'
Field joint
Shop joint
Field joint
2'-6
3'-0"
24"
24"
24"
3'-6"
Bottom of trench
4'-0"
12"
12"
4'-0'
Fort Hill Siphon
R=6'2
3'-11½"
1 on 4
15'
Field joint
Shop joint
Field joint
2-6"
2'3
3'-0"
2'3"
24'
3'-0"
2-6"
18'
4'-0'
4'-0'
Elmsford Siphon
CATSKILL AQUEDUCT – PIPE SIPHONS
CONCRETE CRADLES

Fig. 7.

and other conditions. The pipe is then slowly emptied and preparations made for lining. Methods for placing the concrete jacket have not differed essentially from those usual for concrete conduit construction. On one siphon the jacket was placed by three methods in different parts: (*a*) Monolithic (as specified); (*b*) invert first, then remainder; (*c*) invert and side walls to horizontal diameter, then arch. Best contact between jacket and pipe was obtained when the concrete was placed monolithicly. Dumping concrete on to the pipe so as to cause shock should be avoided; a 2-ft. drop is too great.

The average rate of placing the concrete jacket at Hunters Brook siphon was about 130 ft. a week, the maximum week's work being 223 ft.; at Turkey Mountain siphon, the average was about 170 ft., the maximum week's work being 297 ft.; at Fort Hill siphon, average rate about 190 ft., maximum week's work 260 ft. At Hunters Brook and Fort Hill siphons the concrete covering was usually placed in two operations, the invert being placed first. At Turkey Mountain siphon the concrete covering for the greater portion of the siphon was placed in one operation. Last season at Foundry Brook, the best progress in placing the jacket, using concrete mixed by machine, transported and deposited by cableway, was probably 30 ft. of full section per eight-hour shift, or about 50 yd. of concrete. At Indian Brook the best day's work was about the same under similar conditions. There are many factors which influenced this progress, such as method of mixing (at Foundry Brook last year a large part of the mixing was done by hand), method of transportation — cableway, wheelbarrows, or cars — and style of outside forms, — whether steel or wood and conveniences for moving and setting them. On the siphons just mentioned there were two operations in placing the jacket last year, the first including the concrete under the pipe and in the joint holes and thence up to the horizontal diameter, using when necessary steel or wood outside forms. Earth covering was placed immediately after the completion of the concrete jacket, so there has been little chance to observe the tendency to crack. So far as observed, there have been very few cracks in the jackets of any of the siphons built to this date.

For lining the pipes, two distinctly different methods were at

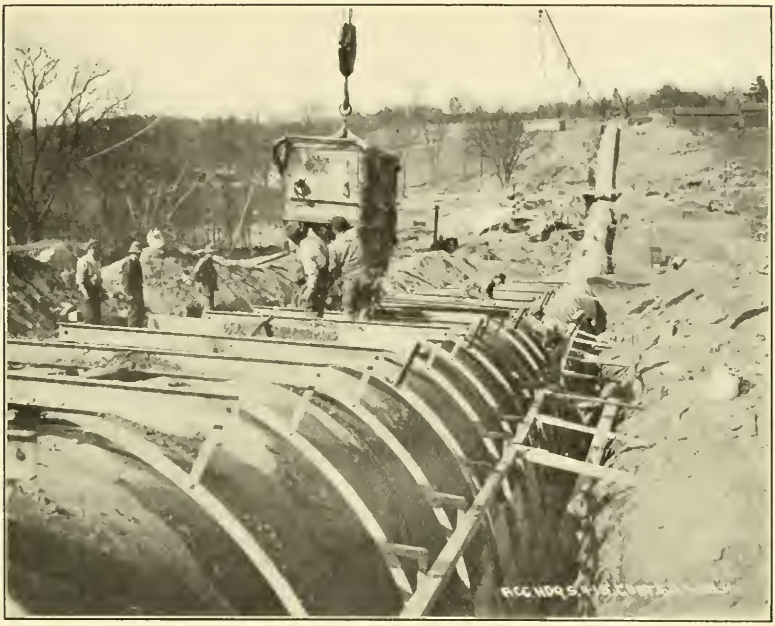


FIG. 1.
FORT HILL SIPHON.
Placing concrete in jacket, with cableway, showing one type of forms.

FIG. 2.
INDIAN BROOK SIPHON.
Wooden forms for mortar lining; completed lining in foreground.

the beginning adopted by the two contractors; on Contract 62 grouting with forms has been employed, and on Contract 68 mortar was applied in the first siphon (Hunters Brook) by means of the "cement gun." Practical difficulties militated against the use of a complete cylindrical form, such as getting around curves, vertical or horizontal; collapsing one section of forms sufficiently to pass forward through another which must remain in place while the grout is hardening; cleaning, lubricating, and inspecting outside of form. Consequently, the invert for a width of about 8 ft. of arc has hitherto been placed first by methods similar to those of concrete sidewalk construction. These wide inverts have generally separated from the pipe along their edges, for one reason or another, so that a piece of steel tape could at places be pushed into the crack for several inches. To obviate this trouble trials are now being made under Contract 68 of inverts 1 ft. to 2 ft. wide.

Under Contract 62, and recently also under Contract 68, wooden forms in panels 2 ft. wide and 15 ft. long (7.5 ft. at curves) adjusted on centers, or wooden ribs, and firmly braced, are used for pouring the remainder of the lining in 15-ft. sections at one operation. The grout is poured from outside the pipe through a $2\frac{1}{2}$-in. wrought-iron pipe secured into a rivet-passing hole. In the Southern Department this pouring pipe is at the downhill end of the section and is long enough to give a head of about 4 ft. on top of the uphill end. A vent pipe is fastened in the uphill rivet-passing hole of the section, the bulkhead forming the end of the lining being placed just below it. For pouring grout the contractor for the northern siphons has always used two mortar boxes set on a temporary staging over the upper end of the section to be grouted. The mortar is mixed to the proper consistence in alternate boxes and is allowed to flow into the pipe through a hole controlled by a sliding wooden gate. All mixing is done by hand, and materials are carefully graded. It generally takes about two hours to fill a section, after which a man is kept on for another hour or two in order to feed in sufficient grout to get the desired consistence. There is a noticeable tendency to get a porous or thin condition at the upper end of the section, near the grouting hole. To avoid this, the riser is removed two or three times during the pouring and the thin material which collects at the top is allowed

to escape. The riser is then put back and grout added until desired results are obtained. In some cases it takes nearly two hours after the main operation to get grout of proper consistence at the foot of the riser. At the finish of the pouring a small pipe is inserted through the large pipe, to permit the escape of the last air while grout is poured through the larger pipe and churned into the small remaining space, to insure complete filling. For the first batches, or nearly up to the horizontal diameter of the pipe, the grout is mixed 1 part cement to 1 part sand, and the remainder about 1 to 2. Lining at Foundry Brook siphon is now being placed at an average rate of about 400 ft. per week, with approximately twelve sets of 15-ft. forms. The contractor's gangs are very efficient at the present time both in handling forms and depositing grout. About two moves per week can be made with each set of forms, and the rate of lining depends on the number of forms and men available.

Engineering Record, July 1, 1911, contains a description of the "cement gun" which is readily available, and so a description of the machine will not be given here. It is shown in one of the illustrations. With this machine the process of lining is to place invert as in the grout method and then build up the arch for the remainder of the circumference in layers placed in rapid succession. Each layer has a rough surface, to which the next adheres well; the first layer on the steel is very thin, and others follow practically continuously at such short intervals that the lining is substantially monolithic. It is impossible to secure a satisfactorily smooth finish with the "cement gun," and so the final layer is floated and troweled before it hardens.

Without further information it is difficult to state the area of mortar lining placed in any interval of time with one cement gun. During the weeks ending July 26, August 2, and August 9, the lengths of pipe lined were, respectively, 204 ft., 254 ft., and 221 ft. For a portion of this time two guns were working, and at times two shifts per day. By both the grouting and the gun methods very smooth interior surfaces are being secured.

In using the cement gun, charges of dry sand and cement mixed in prescribed proportions are placed in the chamber of the machine and then rapidly discharged by air under 50 to 60 lb. pressure

Plate IV.
N. E. W. W. Association,
September, 1911.
Flinn on
Protection of Steel Pipe.

Hunters Brook Siphon.

Cement Guns on concrete jacket; steel manhole, concrete not yet placed around it.

through a rubber hose; through a parallel hose, joining the first in a special nozzle, water under pressure is discharged so that the sprays of water and of sand and cement are combined. The nozzle pressure is about 30 lb. and so the material is thrown with considerable force against the surface to which it is being applied. This aids in securing the excellent union between the layers. The operative holds the nozzle about 2 or 3 ft. from the surface being coated, moving it back and forth continuously. The flow from the nozzle is controlled by means of lever valves.

One result of the high pressure at the nozzle is that a measurable proportion of the sand bounds off the surface upon which the mixture impinges and falls into the bottom of the pipe, especially when beginning the first layer on the bare steel. This dry material, 1 part cement to $3\frac{3}{4}$ parts sand, by analysis, is clean and is collected for use in making invert. In view of this action, an excess of sand is put into the dry mixture, in order that the lining may be no richer than intended. Another incidental result is that the atmosphere inside the pipe is commonly very dusty, and in order to provide reasonable working conditions for the men, artificial ventilation is resorted to. A third result is that the mortar is less well supplied with water than in the grout, and more attention must be given to keeping the lining moist in order to minimize shrinkage cracks. Failure fully to appreciate the necessity for this moistening in the initial use of the gun was probably contributory to the formation of rather numerous fine cracks. Inevitable temperature changes due to the setting of the cement enhance the tendency to crack. In spite of this untoward circumstance, a satisfactory lining has been secured. After completing one siphon the use of the cement gun was discontinued by the contractor, the reason given being excessive cost. As an aid to preventing cracks and a safeguard against the remote possibility of small pieces of the lining becoming loose and falling, provision was made in both contracts for inserting wire fabric in the mortar, but up to date none has been used.

Absolute adhesion of concrete or mortar to the steel is not being secured at all points, as has been proven by careful sounding with a hammer, but on cutting into hollow-sounding spots the space between the mortar or concrete and the steel has usually been found

almost infinitesimal in width. What effect will such failure to adhere have upon the protective action of the lining? No better reply can be made at present than a brief statement of some experiments at the board's laboratory.

One test was arranged as follows: Six steel plates 8 in. by 16 in., of 12 gage, cleaned by pickling and then by rubbing with emery cloth, were placed horizontally in a galvanized iron tank 18 in. in diameter and 24 in. deep, separated from the bottom by two $1\frac{1}{4}$-in. bars of alberene stone, and from each other by $\frac{1}{2}$-in. wood dowels. The first pair of plates was put in without any protective covering. The second pair had their upper surfaces protected by a slab of cement mortar $2\frac{1}{2}$ in. thick, not in contact with the steel, but separated from it by two metal strips about .04 in. thick. The third pair of plates was protected by cement mortar slabs 2 in. thick, cast directly on the steel, and apparently adhering to it firmly. The tank was then filled with Croton water to a depth of 4 in. above the top of the uppermost mortar slab, and kept filled the entire duration of the test, the water being renewed twice monthly.

After two years' immersion, the plates were taken out and cleaned off by washing with a sponge. The first pair of plates showed heavy corrosion. In numerous places the entire layer of oxide had separated from the steel and formed blisters, leaving the bright steel surface underneath. The second pair of plates showed a very slight corrosion. Most of this washed off, thus indicating a considerable protective influence of the mortar slabs even when separated from the metal by a space of .04 in. When the mortar slabs were removed from the third pair of plates, it was found that a part of the surface of the steel had a distinctly different appearance from the other part. One part was clean and wet; the other part was covered by strongly adhering particles of mortar and was dry, thus indicating that there had been actual adhesion of the mortar only over the latter part of the surface and that the former had been separated by a space large enough for the water to enter. There had, however, been no rusting except at some places near the edges of the wet part of the surface, where apparently the space had been big enough to allow circulation of the water. The water in the rest of the space had evidently been so highly charged with lime that no corrosion could take place.

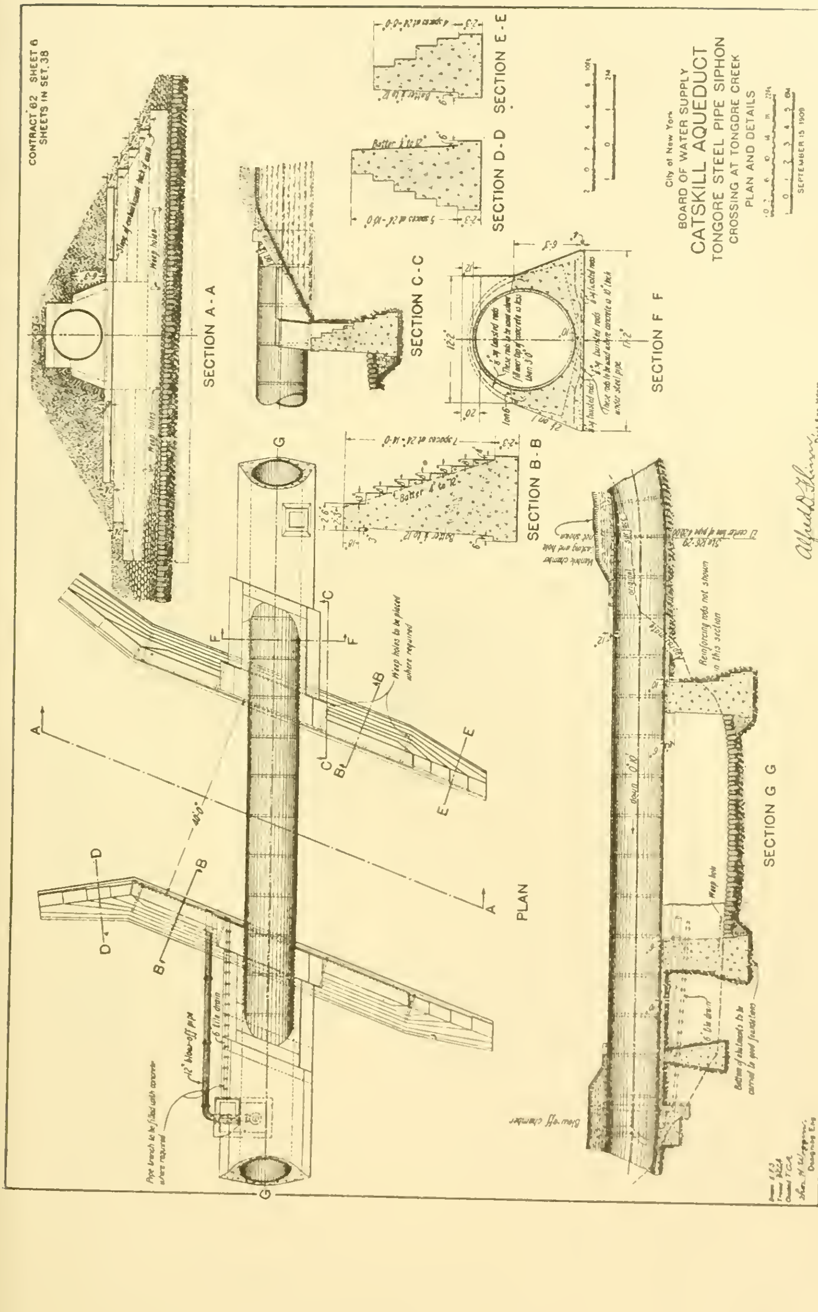


Fig. 8.

Typical Overhead Stream Crossing.

Another test was arranged as follows: Four circular slabs $15\frac{1}{4}$ in. diameter and 3 in. thick were made of concrete in proportions 1 cement: 2.7 Jerome Park screenings: 6.3 Jerome Park stone (gneiss) by weight, the consistence of the mix being rather dry. Carefully imbedded in the center of the slabs were four $\frac{3}{4}$-in. round, soft-steel rods spaced 3 in. apart, so that there was at least $1\frac{1}{2}$ in. of concrete in all directions from the rods. When the concrete had set, two of these slabs were immersed in water in two tanks 1 ft. 6 in. in diameter and 2 ft. deep. The other two slabs had two galvanized-iron cylinders $15\frac{1}{4}$ in. in diameter cemented to them, and a head of 20 in. of water maintained on them. The water in the tanks and cylinders was kept at a constant depth and head by the addition of water whenever it was necessary. The slabs subjected to percolation leaked rapidly at first, but became gradually tighter, and during the last few months of the tests there was very little leakage. The tests were conducted in open air, and were subject to the variations in outdoor temperature. The tests commenced July 13, 1907. On March 23, 1909, one year and eight months later, the slabs were broken and rods examined for corrosion. It was found that the protection of the rods by the concrete was perfect in all cases, there being no sign of corrosion on either the black finish of the metal left by the rolls or on the bright ends of the rods exposed in cutting to length with the hacksaw. The concrete when broken was found to be thoroughly saturated, showing that the water had full access to the rods.

The cost to the city of the pipes and their protection is indicated by the contract prices for the important items given in Table 2. It is too early to compute accurately the cost to the contractors. So large a proportion of the jacketing and lining remains to be done that there is room for improvement in methods or gain in facility of operation with present methods, both of which may affect contractor's costs. Parts of the narrative of this type of construction cannot be written for a few years.

TABLE 2.

CONTRACT PRICES FOR STEEL PIPES, CONCRETE JACKET, AND MORTAR LINING.

Contract 62. Description.	Contract Price.	Average of All Bids. (5 bidders.)
9 ft. 6 in. steel pipe, $\frac{7}{16}$-in. plate, lap jointed	\$31.00 lin. ft.	\$35.50 lin. ft.
9 ft. 6 in. steel pipe, $\frac{1}{2}$-in. plate, lap jointed	35.00 ,, ,,	41.20 ,, ,,
9 ft. 6 in. steel pipe, $\frac{1}{2}$-in. plate, longitudinal seams butt-jointed	40.00 ,, ,,	44.80 ,, ,,
9 ft. 6 in. steel pipe, $\frac{9}{16}$-in. plate, longitudinal seams butt-jointed	43.00 ,, ,,	48.80 ,, ,,
9 ft. 6 in. steel pipe, $\frac{11}{16}$-in. plate, longitudinal seams butt-jointed	47.00 ,, ,,	55.80 ,, ,,
9 ft. 6 in. steel pipe, $\frac{3}{4}$-in. plate, longitudinal seams butt-jointed	50.00 ,, ,,	50.60 ,, ,,
Mortar lining for steel pipes	2.50 ,, ,,	4.90 ,, ,,
Reinforcement of mortar lining for steel pipes,	.02 sq. ft.	.03 sq. ft.
Concrete masonry around steel pipes	6.00 cu. yd.	5.85 cu. yd.
Portland cement	1.75 bbl.	1.74 bbl.
Contract 68.		(8 bidders.)
9 ft. 9 in. steel pipe, $\frac{7}{16}$-in. plate, lap jointed	\$29.00 lin. ft.	\$33.25 lin. ft.
11 ft. 3 in. steel pipe, $\frac{7}{16}$-in. plate, lap jointed	33.00 ,, ,,	37.37½ ,, ,,
11 ft. 3 in. steel pipe, $\frac{1}{2}$-in. plate, lap jointed	38.00 ,, ,,	42.75 ,, ,,
11 ft. 3 in. steel pipe, $\frac{1}{2}$-in. plate, longitudinal seams butt-jointed	46.00 ,, ,,	48.75 ,, ,,
11 ft. 3 in. steel pipe, $\frac{9}{16}$-in. plate, longitudinal seams butt-jointed	50.00 ,, ,,	53.62½ ,, ,,
Mortar lining for 9 ft. 9 in. steel pipe	3.00 ,, ,,	3.56¼ ,, ,,
Mortar lining for 11 ft. 3 in. steel pipe	3.50 ,, ,,	4.04½ ,, ,,
Reinforcement of mortar lining for steel pipe	.02 sq. ft.	.02¾ sq. ft.
Concrete masonry around steel pipe	5.25 cu. yd.	5.78 cu. yd.
Portland cement	1.60 bbl.	1.72½ bbl.

To sum up, the intended constructional results are being substantially attained. Consequently, with information so far collected, it is reasonable to anticipate a close approximation of the desired measure of protection for the steel pipes. One of the greatest obstacles to ideal results, from the point of view of protection of the steel, is the difficulty of getting the pipes jacketed with concrete and covered with earth soon after delivery. The steel mill and fabricating shop naturally push their operations to

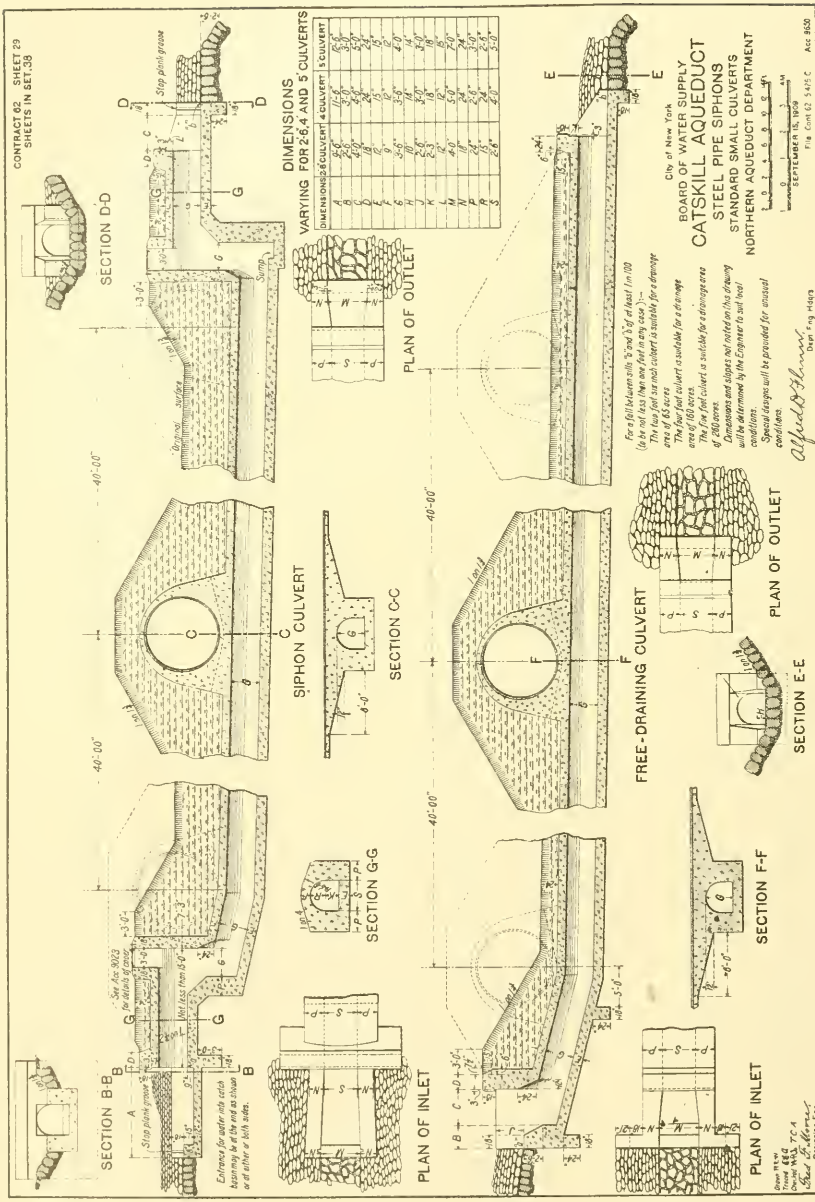


Fig. 9.

All Culverts are built long enough to accommodate future Second and Third Pipe.

completion much more rapidly than the pipe can be laid, tested, and covered.

It is hoped that these pipes will last a hundred years; they may last much longer, barring accidents. Some abuse or unappreciated condition may lead to earlier partial failure, necessitating reconstruction. The gain in smoothness of interior by covering the rivet heads and the plate laps has been computed to so increase the hydraulic capacity that three pipes equal four without lining. The total cost for the siphons with three lined and jacketed pipes is estimated as about the same as for four pipes constructed and coated in the more usual way. Obvious incidental advantages are secured by the more permanent construction.

Engineering operations of the Catskill water works are being directed by J. Waldo Smith, chief engineer, and Merritt H. Smith, deputy chief engineer; Robert Ridgway and Frank E. Winsor are department engineers respectively of the Northern and the Southern Aqueduct departments. In immediate charge of the construction of the siphons are Division Engineers John P. Hogan, Alexander Thomson, Jr., and George P. Wood (Northern); George G. Honness, Ernest W. Clarke, and Charles E. Wells (Southern). The drawings and specifications were prepared and many of the preliminary investigations conducted by Senior Designing Engineer Thomas H. Wiggin, and Engineer Inspector Ernst F. Jonson has had charge of inspection at the rolling mills and pipe shops, all under the immediate supervision of the writer. The chief engineer and his personal assistant, Department Engineer Thaddeus Merriman, made many examinations of existing steel pipes which furnished the reasons for seeking a better protection than the usual coatings.

DISCUSSION.

Mr. John H. Cook. We have some pipes in the plant at Little Falls, which were coated with cement at the time the plant was built, and we have examined them at different times since and concluded it was pretty good protection, the best we have seen. I know of some steel pipes which were coated with cement wash which are now perhaps twenty years old, and they seem to have

stood up pretty well, although there is now no trace of the cement wash left on the pipe.

Mr. Wm. R. Conard. It is usual to use the Rosendale or natural cement for lining pipes, instead of the Portland. I suppose the use of Portland cement in the Catskill Aqueduct work would be more especially because of its quicker setting quality.

The President. It is to be hoped that the steel manufacturers sometime will find a way of making steel so that it will corrode much less rapidly, whether it is protected or not. I wonder if Mr. Speller can tell us something about the possibilities in that direction?

Mr. F. N. Speller. That is something we are all working for, but I do not know whether we can hope to make a steel as non-corrodible as you desire. There has certainly been an improvement in this respect in our time, but at present we all have to depend more or less upon protective coatings. If the pipe could always be taken care of in the way which has been described in Mr. Flinn's paper, I do not think the pipe manufacturers would be so busy, for, after the pipe is all gone, you apparently still have a very good conduit.

Talking about pipe materials, I noted what the speaker said about the possibility that wrought iron might have given better service, and I was gratified to hear him cautiously qualify his remarks in the way he did. I can say from our experience that for welded pipe wrought iron would certainly not have given better satisfaction. It is too late in the evening to take time to give my reasons for this statement, but if I had an hour or so I could give you some very tangible and satisfactory evidence on this point. At all events, while fully realizing the importance of the greatest durability, we have discontinued the use of wrought iron without any hesitation as to the steel now being made for pipe being fully equal and probably superior to wrought iron in this respect.

Mr. J. Waldo Smith. I think that Mr. Flinn has given a pretty full description of what has been done. I might add that what led up to the devising of this coating was the entirely unsatisfactory protection furnished by the coatings which had been used since steel pipe had been laid in the East. About twenty-one years ago, I think, the first pipe was laid for the city of Newark,

and careful examinations have been made of the interiors of those pipes from year to year since that time, as well as in other riveted pipes laid at later dates to which all varieties of asphalt coatings have been applied. They all showed serious deterioration in a short time, usually starting with a small blistering which gradually enlarged until great patches of the coating were separated from the pipe. While it is true that this coating would protect the pipe much better than painting, still there were a great many tubercles and a great deal of pitting, and in places where the coating had come off in large patches this pitting was pretty general in a few years. Knowing this condition, and confirming it still further by recent examinations of pipes, the study which Mr. Flinn has so well described was undertaken, with the result which he has shown. In a way it is, perhaps, going back to fifty years ago, to the time of the cement pipe, the only difference, perhaps, being that the present pipe is riveted and calked absolutely tight, whereas in the old cement pipe the tightness depended more particularly on the lining and on the outer cement coating than on the pipe. The pipe was merely shaped and riveted with cold rivets.

The President. Perhaps the author can tell us something about the acid treatment to remove the mill scale, — how effective it was and about how much per pound it cost.

Mr. Flinn. Mr. President, as to the first part of your inquiry, I can answer from observing the process two or three different times. All the pipes I saw, both for the Board of Water Supply and for another public job, pickled in the same way, by the same contractor, the East Jersey Pipe Company, had the mill scale and the other foreign substances removed from the surfaces of the plate completely. I think it would have been practically impossible to have found on the plates I saw any flake of mill scale or any other foreign substance as big as a dime. Those that were seen were easily swabbed off when the pipe was being transferred from the pickling tank to the washing tank; so that the cleansing of the plates, I should say, was thoroughly successful. As to the cost per pound, I haven't the information on which to base that. It might be somewhat difficult to get it.

Mr. Speller. I would like to comment on the matter of removing the scale. It seems to me a particularly fortunate thing

that so much attention was paid to this matter, as the mill scale is so largely responsible for pitting of iron and steel. Among our experiments we have made a number exposing the same plate, or parts of the same plate, with and without the scale, and found that it makes a very marked difference as to the character of the corrosion whether the plate carries mill scale or does not. I have made some experiments with a plate which had all the scale removed, and a similar piece of steel with only that removed which would accidentally be knocked off in the course of handling the sample; that is, perhaps one tenth of the scale was removed. The corrosion was measured by the loss in weight. In the case where there was considerable scale on the surface, there was deep pitting; and in the other case where the surface was clean, the corrosion was so uniformly distributed that very little damage was done, although the average loss in weight per unit of area was about the same in both cases. I think this is a point that engineers might well bear in mind in considering the protection of iron and steel pipes, viz., the benefit derived from removing the scale before applying any protective coating.

THE PRESIDENT. I think Mr. Speller's remarks upon this point are very important. In some estimates made in our office, some time ago, we allowed a quarter of a cent a pound for treating pipe in this way, but from subsequent developments I am well satisfied that the actual cost is much less than it is figured.

MR. FLINN. I might add one word for the benefit of those who have not had any experience with pickling of steel plates, and that is that a weak solution, a comparatively inexpensive solution, is much more effective in securing a proper cleaning than a strong solution; and a little heat, a temperature of 120° to 125° fahr., greatly accelerates the action of the acid. I should like to know whether Mr. Speller has had similar experience.

MR. SPELLER. We use a 5 per cent. solution of sulphuric acid at about 180° fahr. We think those are the most effective conditions.

A BRIEF DESCRIPTION OF THE GLOUCESTER WATER WORKS.

BY JOHN W. MORAN, SUPERINTENDENT.

[*Read September 13, 1911.*]

The water supply of this city consists of three artificial storage reservoirs, Dikes Brook, Wallace Brook, and Haskell Brook; deriving their supply from well-wooded and uninhabited watersheds, they are free from pollution and furnish a very good quality of water.

The area of Dikes Brook Reservoir is 58 acres; the elevation of the surface, 102 ft.; the watershed area, exclusive of reservoir area, is 376 acres; maximum depth, 24 ft. 6 in.; average depth, 13 ft.; and the storage capacity is 275 000 000. gal.

Wallace Brook Reservoir is 24 acres in area; the elevation of the surface, 63 ft.; the watershed area, 164 acres; maximum depth, 20 ft. 6 in.; average depth, 8 ft.; and the storage capacity is 63 000 000 gal.

Haskell Brook Reservoir is 62 acres in area; the elevation of the surface, 113 ft.; watershed area, 350 acres; maximum depth, 39 ft.; average depth, 23 ft.; and the storage capacity is 475 000-000 gal., of which 285 000 000 only is available for use.

The total watershed area of the three reservoirs is 1 034 acres; the total available storage capacity is 623 000 000 gal., and the consumption at the present time is about 500 000 000 gal. a year.

The estimated daily yield of the three reservoirs in a year of average rainfall is 1 500 000 gal., and the average use in 1910 amounted to 1 343 639 gal. per day.

The water is conveyed from Dikes Brook Reservoir to the pumping station by about a mile of 14- and 16-in. pipe; from Wallace Brook Reservoir to the pumping station by 400 ft. of 14-in. pipe, and from Haskell Brook Reservoir to the pumping station by about $2\frac{1}{2}$ miles of 20-in. pipe. On the line of pipe between Haskell Brook Reservoir and the pumping station there is a high elevation

in the road for a distance of 600 ft., which is $8\frac{1}{2}$ ft. below high-water mark in the reservoir, and it was necessary to lay the pipe 12 ft. below the surface of the road in order to utilize the upper 17 ft. or 285 000 000 gal. of storage.

The pumping station is situated on Magnolia Avenue, near the junction of Essex Avenue, which is on the street-car line of the Essex and Beverly Street Railway. The pumping plant consists of one Knowles duplex compound condensing engine having 16-in. and 30-in. steam cylinders, 16-in. water plungers, a 24-in. stroke, and a capacity of 3 000 000 gal. in twenty-four hours; one Barr pumping engine, vertical, cross-compound, fly-wheel type with steam cylinders 22-in. and 42-in. in diameter, differential water plungers $13\frac{1}{2}$ in. and 19 in. in diameter with a stroke of 30 in. and a normal capacity, at a piston speed of 200 ft. per minute, of 4 000 000 gal. in twenty-four hours; two horizontal tubular boilers each 72 in. in diameter, 130 3-in. tubes 16 ft. long, working pressure 100 lb.; one air pump for charging air chambers; and one electrical generating set for lighting purposes.

The water is delivered from the reservoirs direct to the pumps at a pressure ranging from 12 lb. to 30 lb. per sq. in. on the suction pipe when the pumps are running, and is pumped to a distributing reservoir on Bond's Hill at an elevation of 184 ft. and of about 3 000 000 gal. capacity. Two force mains lead to the reservoir, one being a 16-in. cement lined and the other a 20-in. cast-iron pipe. The two supply mains leading from the reservoir to the city are an 18-in. cement lined and a 20-in. cast-iron pipe, both being laid along Western Avenue through a pipeway, which also accommodates a 12-in. gas main of the Gloucester Gas Light Company, under the canal at the Cut, so called.

The office and stable is on Procter Street, a short distance from City Hall. The stable equipment consists of two horses and three automobiles, one a Maxwell 22-h.p. gasoline runabout, one 1 500-lb. White gasoline truck, and one Cadillac one-cylinder runabout. The blacksmith shop, storehouse, and pipe yard, with a spur track from the Boston & Maine Railroad, are on Arthur Street.

The first works were built by George H. Norman in 1884. In 1895 an act was passed by the legislature authorizing the city of Gloucester to supply itself and its inhabitants with water for

fire, domestic, and other purposes and to take by purchase or otherwise the water from any source within the limits of the city not already taken or purchased by the Gloucester Water Supply Company; also to take water from the Chebacco Lakes in the towns of Essex, Wenham, and Hamilton, with the right to supply the town of Essex, if they so desired, with water for fire, domestic, and other purposes. The act further provided that if the Gloucester Water Supply Company shall notify the mayor of the city that it desires to sell its property, and if within one year from the act the city shall by a majority vote to purchase the water works, it shall thereupon become the property of the city; and in case the city and company shall be unable to agree upon the value of the property, the Supreme Judicial Court shall appoint three commissioners who shall determine the fair value of the property; such value to be estimated without enhancement on account of future earning capacity, or future good-will, or on account of the franchise of the company.

The city took possession of the plant on October 1, 1895, the property of the company at that time consisting of Dikes Reservoir, Wallace Reservoir, pumping station, one pump, two boilers, Bond's Hill Reservoir, house and land on Wallace Court, office building and stable on Procter Street, $23\frac{3}{4}$ miles of cement-lined pipe from 4 in. to 18 in., and $5\frac{1}{2}$ miles of pipe of less diameter than 4 in., making a total of 29 miles of main pipe; 181 hydrants, 192 gates, 2 120 services, 6 fountains, 14 standpipes for filling watering carts, and 46 meters.

Three commissioners were appointed to determine the price to be paid by the city, and the hearings opened December 20, 1897. The value of the plant as testified to by the experts employed by the city was \$300 000, while those employed by the water company placed the value at \$1 300 000. The price settled upon by the commissioners to be paid by the city for the plant was \$576 035. The interest amounted to \$203 965, and the legal and other expenses were over \$100 000 more, making the cost of the original plant to the city about \$900 000.

The city since 1895 has added a new engine room and pumping engine, new boiler room and boilers, Haskell Brook Reservoir, pipeway under the canal, and purchased land enough on Bond's

Hill for a new distributing reservoir; extended mains to Riverdale, Annisquam, Bay View, Lanesville, Eastern Point, Bass Rocks, and other places; relaid $6\frac{1}{2}$ miles of cement-lined pipe with cast-iron pipe, and extended 29 miles of cast-iron pipe.

The main pipe in use November 30, 1910, was 29 miles of cast-iron pipe from 4 in. to 20 in., $17\frac{3}{8}$ miles of cement-lined pipe from 4 in. to 18 in., $22\frac{1}{2}$ miles of pipe less than 4 in. in diameter, 14 miles of which is for summer use and is laid near the surface of the ground and is shut off and drained before freezing weather. The total main pipe is 68.43 miles. There are now 326 hydrants, public and private; 546 valves, 4 530 services, 343 meters, 49 standpipes for filling watering carts, and 11 fountains.

The cost of the works November 30, 1910, was $1 463 936.29, the bonded debt was $1 078 000, with interest at $3\frac{1}{2}$ per cent. and 4 per cent. The annual cost of maintenance is about $23 000.

In past years the reservoirs have during the winter and early spring filled up full to the flow line, or nearly so; but this year, when pumping was started from the Haskell Reservoir, this pond was 7 ft. below the flow line, and Dikes Reservoir was also 7 ft. low at the same time, while the Wallace Reservoir, from which we had been pumping all winter, was 15 ft. below the flow line and practically empty, only 5 ft. of water remaining in it.

The water commissioners, considering the seriousness of the situation, established a regulation prohibiting the use of lawn sprinklers and allowing the use of hose by hand only. By strictly enforcing this regulation, and by the highway department discontinuing about three fourths of the water usually used for street sprinkling by substituting oil, 25 000 000 gal. less were pumped in July and August of this year than in the corresponding months of last year. At the present time, Dikes Brook Reservoir is 4 ft. low, Haskell Reservoir is $14\frac{1}{2}$ ft. low, and Wallace Reservoir is nearly full.

DISCUSSION.

The President. I have been very much interested in hearing about the Gloucester Water Works. I remember that when I was here professionally, fifteen or sixteen years ago, there was a somewhat different story told about the quality of the water

from what we have heard this morning, and that one particular complaint was that the water contained short lobsters. I would like to ask Mr. Moran whether he still finds them.

Mr. Moran. A few in cold weather.

The President. Are you still troubled with tastes and odors, or do you use copper sulphate to hold the organisms down?

Mr. Moran. The only trouble we have now is from Wallace Brook Reservoir, which is a shallow basin, and we do not use the water from that pond in the summer. We have no trouble with the other ponds.

Mr. George Bowers. When you shut off the summer supply to the cottages, how do you get rid of the water in the pipes? Can you draw it all off so that they are empty, or do they freeze up in the winter?

Mr. Moran. The pipes for summer use are laid near the surface, and just before cold weather they are drained and then they are ready for the spring. The reason we use so much of that kind of pipe is that it would be very expensive to reach the summer residences with a deep pipe. The board is relaying some of these pipes every year, and in course of time we hope to replace them all by deep pipe.

The President. How much do you charge for the summer residences, in proportion to the amount charged for houses which are supplied the year round?

Mr. Moran. The summer people pay the annual rate. There is no discount.

A Member. What is the size of the surface pipe?

Mr. Moran. Two inches.

Mr. William F. Sullivan. What is the ordinary rate for a summer house?

Mr. Moran. I could not say what the average is, because some of the houses have a number of bathrooms, four or five. The charge for an ordinary house with one bathroom and hose is \$23. There is an extra charge of \$8 for each additional bathroom.

PURIFICATION OF SALT WATER.

BY ROBERT SPURR WESTON, SANITARY EXPERT, BOSTON, MASS.

[*Read September 13, 1911.*]

The city of Gloucester, Mass., is well known as one of the great fish markets of the world. Here come the trawlers from the Grand Banks, the hand-liners from the Georges, and the mackerel seiners from the waters nearer shore. Here are discharged cargoes of fish, some of which is marketed in a fresh state, but most of which is cured, salted, pickled, smoked, or canned, and finds a market over a wide territory.

By far the most important part of the industry is the preparation of the cod and other salt fish for the market. The other fish which are handled like the cod, in dressing and curing commercially, are the haddock, cusk, hake, and pollack. It is not the writer's purpose to describe this work, but Bulletin No. 133 of the Bureau of Chemistry, United States Department of Agriculture, will prove most interesting to those who desire to study the matter. The author of this pamphlet, Mr. A. W. Bitting, inspector in the Bureau of Chemistry, describes in great detail the study of the industry which he made in 1910. The most important feature of this investigation was a bacteriological study of the causes of the so-called " reddening " of salt codfish. The author states that codfish and some other salt-cured fish are subject to spoilage when exposed to a temperature above 65° F. This spoilage is manifested by the surface of the fish turning red and emitting a foul odor.

The reddening of the codfish is an old difficulty in the industry, but formerly was not of the commercial importance that it is at the present time, for then the business was limited to the cooler months of the year, and such spoilage as did occur in summer was taken as a necessary loss. The improved methods of packing have made the product more attractive to the general consumer, and have created a demand for the product throughout the year, and, at the same time, have made it more perishable and of higher cost.

The loss which occurred was, therefore, more keenly felt, and that which was once thought to be a necessity is now considered preventable.

Mr. Bitting found that the so-called reddening was due to the growth of organisms on the fish, especially a mold-like fungus (*Oidium morrhuæ*), and one of the causes for the growth of these organisms at Gloucester was the impure salt water used for washing the fish. Mr. Bitting writes as follows:

"It is generally agreed among the fish packers that sea water is much to be preferred for washing the fish and making the pickle. Well water or fresh water is said to cause some changes which are objectionable. At the beginning of this study it was understood that the sea water used was obtained at some distance from the plants and that it was pure. In the course of the examination of the fish, organisms were found which were recognized as being ordinarily associated with polluted water, and this led to an investigation as to the cause of their presence. The water used by the packers is from the Gloucester Harbor, and is taken only a few feet from the end of the docks. This harbor is long and narrow, surrounded on three sides by the city, and the surface water from the streets drains into it. Many private sewers and a few fairly large ones discharge into this basin, besides numerous closets upon the docks and those connected with the cottages that overhang the water. All the brine from the butts, the water washing from the fish, and more or less gurry are added to this volume of impurities. The result is a very high bacterial content and the presence of forms that would condemn the water for any domestic use. Tests were made of the water at all the packing plants and at various places in the harbor beyond the breakwater and in the open sea. There was a marked variation in the number of organisms present in the different places and at different stages of tide. In no case could the water be said to be pure within the inner harbor. The long, narrow shape of the harbor and the position of the breakwater preclude the movements of the tide from changing the water each day. A short distance beyond the breakwater, however, and at all points along the eastern coast, pure water was obtained, and this should be used."

Furthermore, the Bureau of Chemistry reported that B. coli had been found on some of the salt fish marketed.

As a result of those reports, it was obvious to many of the fish packers that something must be done to improve the water

supply, and one of the writer's clients installed a mechanical filter, using sulphate of alumina as a coagulant. Partly because of the poor design of the filter itself, and chiefly because of the inadequate provisions for coagulation, the effluent was not at all satisfactory; large numbers of bacteria were present and B. coli were abundant therein.

Accordingly, it was decided to replace this mechanical filter with a slow sand filter of the usual type. This example has been followed by others. The first of these filters, with a capacity of 5 000 gallons per hour, was built for Cunningham & Thompson, of Gloucester. It consists of a wooden tank containing three feet of sand supported upon a one-foot, graded gravel layer. The effluent from the filter discharges through a floating orifice-regulator into the clear-water basin, whence it is pumped to the plant by means of a motor-driven pump controlled automatically by a float-switch; another pump, also controlled by a float-operated automatic switch, supplies water to the filter.

When the filter was designed, the writer could find no precedent to guide him. On general principles he believed that bacteria could be removed from salt water more readily than from fresh water because of the well-known tendency of salt water to coagulate certain kinds of colloidal matter discharged into it. A search of the literature was fruitless, and, aside from a few aquariums where salt water was filtered for use in observation tanks, no examples of salt-water filters could be found on record. It is for the recording of the results of the operation of this filter that this paper is written.

The raw sea water taken from the outer harbor, at the Cunningham & Thompson works, is much purer than the water of the inner harbor. It is, however, polluted with sewage discharged at the southwesterly side of the city, at a point less than 1 000 ft. distant from the intake. A partial analysis of the water was made on November 14, 1910, and the results, showing a slight degree of pollution, are as follows:

Constituent.	Parts per Million.
Nitrogen as free ammonia	0.108
,, ,, albuminoid ammonia	0.112
,, ,, nitrites	0.007

Bacteria at 20° C.	Liquefied plate.
,, ,, 37° C.	.95 per c.c.
B. coli	Present.

The filter was put in operation in May, and since then bacteriological examinations of the influent and effluent have been made with the following results:

Date of Examination.	Total Bacteria per c.c.					
	Growth at 20° cent.		Growth at 37° cent.		B. Coli per c.c.	
	Unfiltered.	Filtered.	Unfiltered.	Filtered.	Unfiltered.	Filtered.
1911						
May 17	1250	350	340	75	8	0.03
,, 24	875	290	192	65	6	0.0
June 6	560	65	75	18	4	0.0
,, 20	665	130	340	62	5	0.0
,, 29	320	49	130	19	7	0.0
July 19	560	75	290	45	4	0.0
Aug. 7	160	42	134	28	2	0.0
Sept. 13	195	35	130	20	7	0.0

The above results show the remarkable removal of coli by the filter, even during the first month of operation, and, furthermore, a reasonable bacterial efficiency. Since June 20 the results, at no time bad, have been very good. It is believed, however, at present writing that, while the removal of B. coli is excellent and satisfactory, the aging of the filter is as necessary for the removal of other bacteria as is the case when fresh water is filtered.

A second filter is now under construction for the Gorton-Pew Fisheries Company. The water to be filtered is from the inner harbor near the landing place of the Boston and Gloucester steamers, and is much more highly polluted than that from the outer harbor. For this reason provision has been made to aërate the water before filtration and to filter at a lower rate than in the previous case.

Two filters, each 21 ft. square, a clear-water basin 32 ft. long by

10 ft. wide by 10 ft. deep, and a pump house 10 ft. square, as well as all the accessory parts, are included in a reinforced concrete structure, about 47 ft. by 36 ft. in area. Nearly the whole of the structure is above ground and rests upon a ledge. The regulating chambers are built within the clear-water basin. These, as well as the filters, are covered with a wooden house, while the clear-water basin and pump house are covered with a concrete-slab roof. The filters are of the usual type and contain 4 ft. of sand supported upon 1 ft. of graded gravel, underdrained with split tiles.

Water from the harbor will be pumped through the aërators into the filters. Filtered water will flow into the regulating chamber inside, from which it will be pumped through a floating regulator consisting of a float and submerged orifice, which, in turn, will discharge into the clear-water basin, whence the water will flow either by gravity to the wharves below or by pumping to an elevated tower tank.

It is estimated that this filter has a capacity of 100 000 gal. in twenty-four hours at a rate of 5 000 000 gal. per acre per diem, or about 80 000 gal. at a 4 000 000-gal. rate.

DISCUSSION.

THE PRESIDENT. This is a very interesting paper, gentlemen. It shows the application of an old process to an entirely new field.

MR. FRANK L. FULLER. I would like to ask Mr. Weston if the organisms in this polluted salt water are similar to those in polluted fresh water.

MR. WESTON. The organism to which objection is made is the ordinary sewerage bacteria, the B. coli. That is the only one which has been criticised, but I imagine that the other sewerage bacteria must be present.

MR. W. H. RICHARDS. I would like to inquire if the filter takes out any appreciable quantity of the salt. I remember that, in the instructions for first aid to the wounded, salt water is referred to as an antiseptic, and I wondered whether the salt water would not have to be more heavily loaded with sewage than fresh water in order to have the same number of germs in it.

Mr. Weston. I don't quite grasp Mr. Richards's question, but I can say that, so far as I know, salt water has a tendency to precipitate organic matter. Mr. Clark made a series of studies in connection with the proposed Charles River Basin in Boston, some years ago, and those studies showed conclusively that sewage would be precipitated by salt water. Of course there would be a tendency to throw down the bacteria in the sewage with the precipitate. As to whether salt water itself is a disinfectant to any great extent, that is a matter which we don't know very much about.

For the first half hour or so the filter reduced the salt, but after that and at the present time there is no reduction in the salt content.

The President. I remember that Prof. William Ripley Nichols made experiments in the filtration of salt water many years ago with reference to that point, and his finding was that no salt whatever was removed by the process.

Mr. Elbert E. Lochridge. It is very interesting to me to see the way in which this system of filtration has been applied to salt water, and for a purpose which is of as much value from the point of view of health, in all probability, as the filtration of some other kinds of water. It is simply along the line of keeping water used in the preparation of food supplies as pure as the water that we use for drinking.

PROCEEDINGS.

NANTASKET BEACH, MASS., June 14, 1911.

The June meeting of the New England Water Works Association was held at Paragon Park, Nantasket Beach, Mass., to-day. Vice-President Collins in the chair.

The following members and guests were present:

MEMBERS.

S. A. Agnew, G. A. P. Bucknam, James Burnie, T. J. Carmody, M. F. Collins, Albert S. Glover, R. K. Hale, F. E. Hall, Willard Kent, G. A. King, C. F. Knowlton, A. R. McCallum, A. E. Martin, W. E. Maybury, John Mayo, F. L. Northrop, C. E. Peirce, G. H. Snell, G. T. Staples, W. M. Stone, D. N. Tower, L. J. Wilber, F. B. Wilkins. — 23.

ASSOCIATES.

Anderson Coupling Company, by Charles E. Pratt; Builders Iron Foundry, by A. B. Coulters; Chadwick-Boston Lead Company, by A. H. Brodrick; Allyne Brass Foundry Company, by B. T. Beardsley; Darling Pump and Manufacturing Company (Ltd.), by H. H. Davis; The Fairbanks Company, by A. W. Farwell; W. H. Gallison Company, by P. J. Lynch; Hersey Manufacturing Company, by Albert S. Glover; Lead Lined Iron Pipe Company, by T. E. Dwyer; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Norwood Engineering Company, by C. E. Childs; Rensselaer Valve Company, by F. S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Water Works Equipment Company, by H. M. Heim; Henry R. Worthington, by Samuel Harrison and E. F. Nye. — 20.

GUESTS.

Miss Inez Stryker, Everett, Wash.; Mrs. C. F. Knowlton, Melrose, Mass.; Fred E. Sharp, Whitman, Mass.; Mrs. T. J. Carmody, Miss Katherine Sullivan, Holyoke, Mass.; Mrs. John J. Sullivan, Bangor, Me.; Charles E. Johnson, North Andover, Mass.; Mrs. C. E. Peirce, East Providence, R. I.; Mrs. Fred S. Bates, Troy, N. Y.; Mrs. L. J. Wilber, Campello, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mrs. W. E. Maybury, Mr. and Mrs. R. D. Wetherbee, Braintree, Mass.; F. W. Matthers, Boston, Mass.; George

McKay, Jr., Philadelphia, Pa.; F. B. Wilkins, Woonsocket, R. I.; Mrs. H. H. Kinsey and Mrs. E. M. Shedd, Boston, Mass.; Mrs. B. T. Beardsley and Miss H. M. Beardsley, Detroit, Mich.; John Kelly, water commissioner, Braintree, Mass.; and I. S. Holbrook, of the *Engineering Record*, New York, N. Y. — 23.

The Secretary presented applications for membership from the following, properly endorsed by the Executive Committee:

T. J. McCarthy, city engineer, Holyoke, Mass.; Henry R. Buck, consulting engineer, Hartford, Conn.; Arthur W. Jepson, manager Bristol Water Company, Bristol, Conn.; Charles T. Treadway, president Bristol Water Company, Bristol, Conn.; Charles E. Johnson, superintendent Board of Public Works, North Andover, Mass.; Frank L. Anders, city engineer, Fargo, No. Dak.; Raymond W. Parlin, resident engineer, Washington County Water Company, Hagerstown, Md.

The Secretary was directed to cast the ballot of the Association in favor of the applicants, and he having done so they were declared elected.

The Thirtieth Annual Convention.

Gloucester, Mass.,
September 13, 14, 15, 1911.

The Thirtieth Annual Convention of the New England Water Works Association was held at Gloucester, Mass., September 13, 14, and 15, 1911.

The headquarters of the Association were at the Hawthorne Inn, East Gloucester. The sessions of the convention were held in the Casino adjoining the Inn, where also were provided accommodations for the exhibits of associates.

The following members and guests were present:

Honorary Members.

Frederic P. Stearns. — 1.

Members.

S. A. Agnew, M. N. Baker, C. H. Baldwin, L. M. Bancroft, F. A. Barbour, F. D. Berry, C. R. Bettes, F. E. Bisbee, A. E. Blackmer, J. W. Blackmer, E. C. Brooks, George Bowers, James Burnie, C. E. Chandler, T. J. Carmody,

W. F. Codd, M. F. Collins, W. R. Conard, J. H. Cook, H. R. Cooper, E. R. Dyer, E. D. Eldredge, J. L. Dower, G. H. Finneran, A. D. Flinn, F. L. Fuller, T. C. Gleason, A. S. Glover, W. B. Goentner, J. M. Goodell, J. W. Graham, F. E. Hall, D. A. Hartwell, W. C. Hawley, Allen Hazen, D. A. Heffernan, W. R Hill, George Holtzmann, F. T. Kemble, Willard Kent, G. A. King, J. J. Kirkpatrick, C. F. Knowlton, B. C. Little, E. E. Lochridge, F. H. Luce, T. J. Lynch, T. J. MacCarthy, Daniel MacDonald, T. H. McKenzie, A. E. Martin, W. E. Maybury, F. E. Merrill, G. F. Merrill, J. W. Moran, F. L. Northrop, A. E. Pickup, A. A. Reimer, W. H. Richards, Robert Ridgway, G. A. Sanborn, P. R. Sanders, A. L. Sawyer, J. E. Sheldon, J. Waldo Smith, G. H. Snell, F. N. Speller, G. A. Stacy, G. T. Staples, W. F. Sullivan, H. L. Thomas, R. J. Thomas, S. F. Thomson, J. L. Tighe, D. N. Tower, C. H. Tuttle, J. H. Walsh, R. S. Weston, G. C. Whipple, J. C. Whitney, L. J. Wilber, G. E. Winslow, I. S. Wood, and L. C. Wright. — 84.

Associates.

Anderson Coupling Company, by Chas. E. Pratt; H. L. Bond Company, by F. M. Bates and G. S. Hedge; Builders Iron Foundry, by D. W. Bartlett, A. B. Coulters, and F. N. Connet; Chapman Valve Manufacturing Company, by H. L. DeWolfe; Darling Pump and Manufacturing Company (Ltd.), by H. H. Davis; The Fairbanks Company, by A. W. Farwell and W. D. Cashin; Gamon Meter Company, by C. A. Vaughan; Glauber Brass Manufacturing Company, by Sam. Davis and S. S. Freeman; Hart Packing Company, by Horace Hart; Hays Manufacturing Company, by C. E. Mueller and T. J. Nagle; Hersey Manufacturing Company, by A. S. Glover and H. D. Winton; Lead Lined Iron Pipe Company, by T. E. Dwyer and E. J. Stark; Ludlow Valve Manufacturing Company, by H. F. Gould and G. A. Miller; Charles Millar & Son Company, by C. F. Glavin; H. Mueller Manufacturing Company, by O. B. Mueller, G. A. Caldwell, and A. C. Pilcher; National Meter Company, by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; National Water Main Cleaning Company, by D. H. Buell; Neptune Meter Company, by F. A. Smith, H. H. Kinsey, R. D. Wertz, and T. D. Faulks; Pittsburg Meter Company, by T. C. Clifford, V. E. Arnold, and F. L. Northrop; Rensselaer Valve Company, by C. L. Brown; Ross Valve Manufacturing Company, by William Ross; A. P. Smith Manufacturing Company, by T. F. Halpin, F. N. Whitcomb, and D. F. O'Brien; Standard Cast Iron Pipe and Foundry Company, by W. E. Dodds; Standard Water Meter Company, by A. S. Merrill; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall; Waldo Brothers, by H. E. Browne; Water Works Equipment Company, by W. H. Van Winkle and H. N. Hein; R. D. Wood & Co., by C. R. Wood; and Henry R. Worthington, by Samuel Harrison, E. F. Nye and George Carr. — 54.

Guests.

Mr. F. L. Cole, Andover, Mass.; Mrs. A. A. Reimer, East Orange, N. J.; Mrs. D. N. Tower, Cohasset, Mass.; Mrs. Thomas J. Carmody, Miss C. Ryan,

Holyoke, Mass.; Mrs. W. J. Wilber, Brockton, Mass.; Master Neddie Eldredge, Onset, Mass.; Harold H. Sinclair, Bangor, Me.; Mrs. George Holtzmann, Schenectady, N. Y.; F. W. Dinwiddie, Gardner, Mass.; Mrs. E. E. Lochridge, Springfield, Mass.; Thomas P. Taylor, Boston, Mass.; Mrs. C. R. Bettes, Far Rockaway, N. Y.; Mrs. O. B. Mueller, New Rochelle, N. Y.; Miss Joan M. Ham, Boston, Mass.; Mrs. F. H. Luce, Woodhaven, N. Y.; Miss Lillian G. Dillaway, Mrs. C. F. Knowlton, Melrose, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mr. and Mrs. James P. Bacon, Cambridge, Mass.; E. F. Hughes, Boston, Mass.; Mrs. L. M. Bancroft, Reading, Mass.; Mrs. R. J. Thomas, Mrs. George Bowers, James G. Hill, Lowell, Mass.; Mrs. I. S. Wood, Providence, R. I.; Marshall G. Richey, Isaac Poor, F. S. Camlin, and F. A. Hall, Haverhill, Mass.; C. A. Goodhue, Thompsonville, Conn.; Mrs. Henry D. Winton, Miss Laura J. Dillaway, Mrs. F. L. Fuller, Clifford D. Winton, Paul J. Dedrickson, Wellesley Hills, Mass.; Mrs. Robert Ridgway, Poughkeepsie, N. Y.; Mrs. William F. Codd, Nantucket, Mass.; Mr. and Mrs. J. J. Desmond, Lawrence, Mass.; Mrs. George H. Snell, Attleboro, Mass.; A. J. Provost, I. S. Holbrook, of *Engineering Record*, Henry A. Johnston, of *Fire and Water Engineering*, A. R. Murphy, New York City; Mr. and Mrs. J. B. Longley, Lewiston, Me.; Mrs. George E. Winslow, Waltham, Mass.; Mrs. S. E. Thomson, New Paltz, N. Y. — 50.

Wednesday, September 13, Morning Session.

The convention was called to order at 11 o'clock by Allen Hazen, the President, and Mayor Isaac Patch, of Gloucester, was immediately presented. He spoke as follows:

Gentlemen of the New England Water Works Association, — On behalf of the citizens of Gloucester I wish to extend to all of you a very cordial welcome to our city. This is the first time that your Association has met in Gloucester, and I trust that you will enjoy yourselves on this picturesque point of Cape Ann as much as we enjoy having you with us, and I hope you will decide to come again.

I congratulate you on your organization, and on this, your thirtieth annual convention. You meet each year to discuss the various problems which confront you from time to time on the subject of water works, which is of vital interest to all of us. After looking over the program which has been presented to me, I feel sure that the papers which are to be read will be very beneficial and instructive to all, and we are indebted to you for coming here this year and giving us the results of your experiences.

Our water department is managed by three commissioners

elected by the municipal council, consisting of five members, including myself. It has been a separate organization since the city acquired the plant from a private company in 1895. The council appropriates the money and the commissioners spend it. We have been fortunate in having as manager of our water department a very able and thoroughly equipped man, who has been at the helm ever since our city took charge, and he has performed valuable service to the city of Gloucester.

I think I would better not weary you by telling you what I know about water, as this has been a dry year in Gloucester in more senses than one. However, there is one thing that I wish to state, and that is that wherever you go, you cannot find any better water than that which the people of Gloucester drink every day.

While you are attending this convention, I want you to be sure to have a good time during your stay with us, and I trust that you will become better acquainted with our city with all its natural beauty.

Gloucester was first settled in 1623, and the colony which established itself on the land which is now the city park across the harbor had for its object the pursuit of the fisheries, which have been carried on here ever since, with the possible interruption of a few years in the early part of the seventeenth century. It is no wonder, then, that the name of Gloucester is known everywhere.

You are to have the experience of a fishing trip on Friday, which I am sure you will enjoy, although it will not be similar to a trip to the Grand Banks. If you have the time, you would be interested in looking through the packing houses where the fish is prepared for market. You would then be able to witness for yourselves the method of conducting our fishing industry on shore, and it would be apparent to you why Gloucester leads all in its excellently prepared fish products.

Gloucester's attractive location and picturesque scenery make it the great and popular summer resort that it is, and people come from all parts of this country to spend their summers with us.

I do not wish to take any more of your time this morning except to say again that we are extremely pleased to have you with us, and hope that you will thoroughly enjoy yourselves and will come again soon.

The President. In behalf of the Association I thank you most warmly, Mr. Mayor, for the cordial invitation and welcome to the city. I know that we shall want to visit the packing houses, and I, for one, remembering former visits, want to "box the Cape" and visit those great granite quarries where the paving stones that we see used all over the United States are cut out and split. We got some idea of the picturesqueness of Gloucester on our way through the narrow crooked streets from the station, features of an older civilization than are exhibited, perhaps, in our more recently built cities, and we shall renew here some of our ideas of early history. I assure you that the members of the Association are very glad to be in Gloucester.

The first business in order was the election of members. The Secretary read the following names of applicants, all of whom had been approved by the Executive Committee.

Active: William A. Carstensen, Winthrop, Mass., water commissioner; Stephen E. Keefer, Berkeley, Cal., engaged in general and consulting practice covering water works, sewage disposal plants, land reclamation, and hydro-electric power development; J. Albert Robinson, Canton, Mass., superintendent fire records, National Fire Protection Association; John L. Dower, Hartford, Conn., president board of water commissioners; W. S. Cramer, Lexington, Ky., chief engineer in charge of the water system of the city of Lexington; George T. Evans, Manchester, Mass., superintendent; J. B. Longley, Leominster, Mass., superintendent.

On motion of Mr. Lewis M. Bancroft, the Secretary was directed to cast the ballot of the Association in favor of the candidates named, and he having done so they were declared by the President to be duly elected members of the Association.

Frederic P. Stearns, chairman of the Committee on Yield of Drainage Areas, submitted the following report:

September 9, 1911.

Mr. Willard Kent, *Secretary New England Water Works Association*,

715 Tremont Temple, Boston, Mass.

Dear Sir, — The Committee on Yield of Drainage Areas held a fully attended meeting on March 8, 1911, when it discussed at length the scope of the

work of the committee and discussed in much detail the nature of the inquiries which should be made in order to obtain the desired information.

Mr. H. K. Barrows was appointed secretary, and he has prepared, in accordance with suggestions made at that meeting, circular letters and blank forms which have been submitted to each member of the committee and which will soon be sent to members of the Society and others having valuable information as to the yield of streams. The remarkable drought of 1911, as it affects water supplies depending upon the storage of water from comparatively small drainage areas, leads the committee to conclude that no inquiry would be complete which did not include information as to the run-off to the end of the present drought, and for this reason the sending out of the circulars and blanks has been purposely delayed.

Very truly yours,

Frederic P. Stearns, *Chairman.*

On motion of Mr. Robert J. Thomas it was voted that the President appoint a Nominating Committee to bring in a list of officers for the year 1912. The President subsequently appointed as members of the committee, Edwin C. Brooks, John C. Whitney, William F. Sullivan, E. E. Lochridge, and W. C. Hawley.

John W. Moran, superintendent of the Gloucester Water Works, read a paper giving a brief description of the works.

Afternoon Session.

Mr. W. H. Richards, engineer and superintendent of the Water and Sewer Department, New London, Conn., presented a paper entitled "Coming Efficiency in Water-Works Management." The paper was discussed by Messrs. A. E. Martin, A. L. Sawyer, T. J. Carmody, Arthur E. Reimer, M. N. Baker, W. C. Hawley, George A. King, and Frank L. Fuller.

Mr. Robert Spurr Weston, sanitary expert, Boston, Mass., read a paper entitled "The Filtration of Salt Water," in which he described the process of purifying water used in the curing of fish at Gloucester. The paper was discussed by Mr. Frank L. Fuller, Mr. W. H. Richards, and Mr. E. E. Lochridge.

Evening Session.

The President. In the new work for the increased water supply for New York City it is necessary to do a great deal of construction in the watersheds of the present supply of New York,

Yonkers, and Peekskill, and perhaps some other places. The measures that have been taken to prevent the pollution of these supplies by the workmen engaged on the construction of the new work have been very novel and, I believe, absolutely unprecedented. It has seemed to me most desirable that these measures should be described to the members of this Association and to be made a matter of record. The chief engineer of the work suggested that Mr. Provost, who has charge of most of this work, should give the description. I have the pleasure of introducing to you Mr. Provost.

Mr. A. J. Provost, New York City, then read his paper entitled "Protection of New York's Water Supply from Pollution during Construction Work." He was followed by Mr. Robert Ridgway, department engineer, Board of Water Supply, New York City, with a paper on "Hudson River Crossing of the Catskill Aqueduct." Both these papers were illustrated by stereopticon views.

Thursday, September 14. Morning Session.

The President. The first matter on the program this morning is the reading of a paper by Mr. Hardolph Wasteneys, Rockefeller Institute for Medical Research, New York City. Mr. Wasteneys is unfortunately unable to be here this morning, being in the South on a trip which could not be postponed. He was formerly chemist of the Brisbane Water Works, and was there at the time of my visit. The results which had been obtained in treating the water were unusual and interesting, and I think have an application to a good many reservoir waters in this country. I want to say just a few words about the character of this water, so you will understand what the problem was.

Brisbane is in the edge of the tropics. A large part of the reservoir is not very deep, and vegetation grows with great luxuriance. Whenever the reservoir is drawn down, vegetation grows on the sides and forms a mass of material that men are working on cutting out constantly. If it was not for that, the reservoir would almost fill up with this vegetation. A water of that type, which is very much like the Ludlow water at Springfield, only more so, and like the Goose Creek water at Charleston, and like the waters on the Isthmus of Panama, is devoid of oxygen, because the decompo-

sition of the organic matters takes it up, and it ordinarily contains ferric iron. It is a water which is impossible of being successfully treated by sand filters as ordinarily constructed, and it is also impossible to treat it by mechanical filters as ordinarily constructed and operated. The problem was the treatment of this kind of water, a water which is sometimes available and is the only water which can be used where water is wanted.

Mr. Robert Spurr Weston then read the paper, which was entitled "A Short Account of Some Purification Experiments with a Surface Water in Queensland, Australia." The paper was discussed by Mr. Weston, Mr. E. E. Lochridge, and the President.

THE PRESIDENT. The next order of business is "Topical Discussion." Has any one any matter to bring up? The Secretary tells me that he understood there was to be some discussion as to the increase of water consumption during the recent hot weather.

MR. FRANK L. FULLER. At Wellesley we have a ground water supply, and although the consumption was greater during the hot months this summer than ever before, we still had plenty of water, perhaps partly due to some extra wells which we drove last fall and winter. We used less water on the streets than usual; I presume, on account of the use of Tarvia and oil and various other materials.

MR. ALFRED D. FLINN. I understand that the normal consumption of Croton water, which is about 340 million gallons per day, has been forced down to about 260 millions, in spite of the unusually warm weather, by the influence of newspaper agitation and warnings to the people. This has involved, however, a curtailment of legitimate uses of water as well, probably as a reduction of the waste in manufacturing places and apartment houses and private dwellings.

The President then showed about fifty views of California, including water works and other subjects, taken from negatives made by himself a few weeks ago, with a running description covering the present sources of supply for the city of San Francisco, owned by the Spring Valley Water Company, and the proposed sources in the Sierra Mountains.

Mr. William F. Sullivan, at the request of the President, in the

absence of Herman M. Peck, civil engineer, Hartford, Conn., its author, read a paper entitled "Organization and Efficiency."

Evening Session.

The Secretary read the following list of applicants for membership, approved by the Executive Committee:

Active: Clifford M. King, Sandusky, Ohio, chief engineer of the Department of Public Service of the city of Sandusky, in charge of the Water-Works Division; Harold H. Sinclair, Bangor, Me., assistant superintendent; Frank L. Cole, Andover, Mass., superintendent; Richard L. Tarr, Gloucester, Mass., foreman water works.

Associate: Grip Coupling Company, Ware, Mass., manufacturers of pipe specialty fittings; *The Engineering Record*, New York City.

On motion of Mr. John C. Whitney, the Secretary was instructed to cast the ballot of the Association in favor of the applicants named, and he having done so they were declared duly elected members of the Association.

Mr. Alfred D. Flinn, department engineer, Board of Water Supply, New York City, read a paper entitled "Protection of Steel Pipes in the Catskill Aqueduct." The paper was illustrated by stereopticon views. Mr. John H. Cook, Mr. W. R. Conard, Mr. F. N. Spiller, and Mr. J. Waldo Smith took part in the discussion.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association was held at Paragon Park, Nantasket Beach, Mass., on Wednesday, June 14, 1911.

Present: Vice-President Michael F. Collins, William E. Maybury, Richard K. Hale, and Willard Kent.

Applications of the following-named persons were approved and recommended to the Association for election to membership.

T. J. McCarthy, city engineer, Holyoke, Mass.; Henry R. Buck, consulting engineer, Hartford, Conn.; Arthur W. Jepson, engineer Bristol Water Company, Bristol, Conn.; Charles T. Treadway, president Bristol Water Company, Bristol, Conn.; Charles E. Johnson, superintendent Board of Public Works, North Andover, Mass.; Frank L. Anders, city engineer, Fargo, No. Dak.; Raymond W. Parlin, resident engineer Washington County Water Company, Hagerstown, Md.

Adjourned.

WILLARD KENT, *Secretary*.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., Thursday, July 13, 1911, at 11 o'clock A.M.

Present: Vice-President Michael F. Collins, William E. Maybury, Lewis M. Bancroft, Richard K. Hale, Robert J. Thomas, and Willard Kent.

Mr. Sherman of the Committee on Annual Convention being called away by business engagements, it was

Voted: That Mr. William E. Maybury be and hereby is made a member of that committee in place of Mr. Sherman.

Voted: That the annual convention of this Association be held in Gloucester, Mass., on the 13th, 14th, and 15th of September next.

Voted: That Mr. F. N. Whitcomb, of the A. P. Smith Manufacturing Company, be and hereby is made the Committee on Associates' Exhibits at the annual convention to be held in September next.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., Tuesday, August 15, 1911.

Present: Vice-President Michael F. Collins, Lewis M. Bancroft, Richard K. Hale, John J. Kirkpatrick, Leonard Metcalf, Robert J. Thomas, and Willard Kent.

Mr. Maybury, of the Committee on Annual Convention, reported satisfactory arrangements for holding the convention at the Hawthorne Inn, Gloucester, Mass.

After discussion of desirable topics for future literary programs, the meeting adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at the Convention Hall, Hawthorne Inn, Gloucester, Mass., September 13, 1911.

Present: President Hazen, and members Irving S. Wood, William E. Maybury, Lewis M. Bancroft, Robert J. Thomas, and Willard Kent.

Seven applications for membership were received and recommended for admission, namely:

For membership, William A. Carstensen, water commissioner, Winthrop, Mass.; Stephen E. Kieffer, consulting engineer, San Francisco, Cal.; J. Albert Robinson, fire protection engineer, Boston, Mass.; John L. Dower, president board of water commissioners, Hartford, Conn.; George T. Evans, superintendent Gloucester Water Works, Gloucester, Mass.; W. S. Cramer, chief engineer water works, Lexington, Ky.; J. B. Longley, superintendent water works, Lewiston, Me.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association, at Hawthorne Inn, Gloucester, September 14, 1911.

Present: President Hazen, and members Irving S. Wood, William E. Maybury, Lewis M. Bancroft, J. Waldo Smith, Robert J. Thomas, and Willard Kent.

Five applications were received and recommended for admission, namely:

For membership: Harold H. Sinclair, assistant superintendent water works, Bangor, Me.; Richard L. Tarr, foreman Gloucester Water Works, Gloucester, Mass.; Clifford M. King, chief engineer Department Public Service, Sandusky, Ohio; Frank L. Cole, superintendent water works, Andover, Mass.

For associate membership: Grip Coupling Company, Ware, Mass.

Adjourned.

WILLARD KENT, *Secretary.*

OBITUARY.*

Walter Herbert Sears, for about five years chief engineer of the Aqueduct Commissioners, in charge of the extensions of the Croton water supply of the city of New York, died October 7, 1911, at his home in Plymouth, Mass.

Mr. Sears was born in Plymouth, in 1847, and graduated from the Massachusetts Institute of Technology in 1868. The following year was spent on Prospect Park, Brooklyn, and the second year in the office of Mr. John B. Henck, civil engineer, Boston. From 1872 to 1874 Mr. Sears was chief engineer constructing water works for Winchester, Mass.; from 1875 to 1879 he held a similar position in charge of preliminary surveys and construction of water works for Pawtucket, R. I.; in the year 1880-1881, as chief engineer, he constructed water works for Stillwater, Minn.; and in 1882–1883 an extension of the water-works system of Winchester, Mass. In 1883–1884 he was an assistant engineer of the American Bell Telephone Company, placing wires underground in the vicinity of Boston and Washington. As resident engineer he constructed a new water supply for Beverly, Mass., in 1885 to 1887, and the following two years were spent as chief assistant engineer of the East Jersey Water Company, at Paterson, N. J. In 1891 he was chief assistant engineer on the additional water supply of Rochester, N. Y. For the succeeding ten years Mr. Sears was engaged in general engineering practice, including renewal of the water-supply systems of Plymouth and Lincoln, Mass., and plans for a new water supply for Grand Rapids, Mich. In 1903 he became department engineer under the Commission on Additional Water Supply, appointed by Mayor Low to investigate Catskill and the other water projects for New York City, Mr. Sears having charge of the Catskill department. Following this engagement Mr.

* Memoir prepared by Alfred D. Flinn.

Sears was resident engineer for the Northern New Jersey Flood Commission, with offices at Paterson, N. J. In 1904 he became division engineer of the Croton River Division of the Aqueduct Commissioners and had charge of work in the vicinity of Katonah, N. Y. From August 1, 1905, to January 9, 1906, he was acting chief engineer, and from the latter date to April 1, 1910, chief engineer of the Aqueduct Commissioners; during this period the Cross River reservoir was completed and the Croton Falls reservoir construction begun and carried nearly to completion. During the latter part of his engagement Mr. Sears was taken ill and was unable to return to active work.

He was a member of the American Society of Civil Engineers from October 5, 1904. Mr. Sears was elected a member of the New England Water Works Association on September 13, 1899.

MEMBERSHIP.

ADDITIONS.

(July 1 to November 1, 1911.)

MEMBERS.

Carstensen, William A.
Water Commissioner, 24 Lincoln Terrace, Winthrop, Mass.

Cole, Frank L.
Superintendent Board of Public Works, Andover, Mass.

Cramer, W. S.
Chief Engineer and Superintendent Water Works, Lexington, Ky.

Dower, John L.
President, Board of Water Commissioners, Hartford, Conn.

Evans, George T.
Superintendent Water Works, Manchester, Mass.

Kieffer, Stephen E.
Consulting Engineer, Mechanics Institute Building, San Francisco, Cal.

King, Clifford M.
Chief Engineer, Department Public Service, Sandusky, Ohio.

Longley, J. B.
Superintendent Water Works, Lewiston, Me.

Robinson, J. Albert
Superintendent Fire Records, National Fire Protection Association, 87 Milk Street, Boston, Mass.

Sinclair, Harold H.
Assistant Superintendent Water Works, Bangor, Me.

Tarr, Richard L.
Foreman, Gloucester Water Works, Gloucester, Mass.

ASSOCIATE.

Engineering Record
239 West 39th Street, New York, N. Y.

Grip Coupling Company
Ware, Mass.

CHANGES OF ADDRESS.

MEMBERS.

Barnes, William T.
With Metcalf & Eddy, Harris Trust Building, Room 1824, Chicago, Ill.

Bush, Edward W., C. E.
Chief Engineer, Lyme, Conn.

Fuller, William B.
Care Mexican Northers Power Company, Ltd., Santa Rosalie, Chihuahua, Mexico.

Glendenning, H. J.
Care Sewerage Commission, Milford, Mass.

Gregory, John H.
Rudolph Hering & John H. Gregory, Consulting Engineers, 170 Broadway, New York, N. Y.

Letton, Harry P.
213 E. Hanover Street, Trenton, N. J.

Perkins, John H.
114 Marshall Street, Watertown, Mass.

Philbrick, Burton G.
Eaton-Philbrick Laboratories, 444 Market Street, San Francisco, Cal.

Priest, George W.
General Manager, Lloyd & Richards, Inc., Point and Erie Streets, Camden, N. J.

Saville, Charles
Assistant Engineer, 170 Broadway, New York, N. Y.

Taylor, Edwin A.
186 Ford Street, Portland Ore.

Van Winkle, Walton
Salem, Ore.

Young, Henry A.
Civil Engineer, Room 340, Produce Exchange Building, New York, N. Y.

DEATHS.

McCallum, A. R.
Superintendent Water Works, Whitman, Mass. September 4, 1911.

Sears, Walter H.
Plymouth, Mass. October 7, 1911.

New England Water Works Association.

ORGANIZED 1882.

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COMING EFFICIENCY IN WATER-WORKS MANAGEMENT.

BY W. H. RICHARDS, ENGINEER AND SUPERINTENDENT OF WATER AND SEWER DEPARTMENT, NEW LONDON, CONN.

[*Read September 13, 1911.*]

Much has been written of late of scientific efficiency, the aim being to get a greater return with less effort, but behind this movement is the increasing desire to promote that efficiency which saves material as well as labor and thus reduces cost of output. So strongly has this idea taken hold of the people that the day is nor far distant when the management of at least all the larger corporations both public and private will be judged by the resulting cost.

So far as water departments either public or private are concerned, this will first manifest itself in the cities of medium size. And it is important that this society consider some of the ways in which this demand must be met, and it is with this in view that this paper is presented.

Whatever of criticism will be found in this paper applies with equal force to private companies or public corporations, as lack of efficient management is found as often in one as in the other, and in the final analysis the public pays in each case.

To promote the greatest efficiency the board of managers or commission, by whatever name it may be called, should be non-political and its duties should be strictly separated from the executive part of the work, being confined to matters of general policy, approval of expenditures, appropriations, general plans, formula-

tion of rules, etc., appointment and removal of subordinates being made only on recommendation of the general manager, superintendent, engineer, commissioner, or whatever title may be given to the executive head, for upon the latter rests or should rest mainly the responsibility for the efficiency of the work. For the remainder of this paper he will be referred to as the superintendent.

What kind of a man should the superintendent be? Not necessarily an engineer in the sense of being a graduate with a "sheepskin," but he certainly should be an engineer in the larger sense that he should be ingenious, capable of interpreting a drawing or making one if necessary, with a thorough knowledge of construction and tools, and he must have or immediately acquire a knowledge of the fundamental principles of hydraulics, and over and above all else he should understand the principles of business management. Such a man, it is perhaps unnecessary to state, cannot be secured for twelve or fifteen hundred dollars per year. If the organization be a new one, several years must elapse in experiments, and usually the "fads and fancies" of the superintendent have to be tried out and their utility tested. Even with the above qualifications he has much to learn, for the management of water works requires much special knowledge.

The powers of the superintendent should be large, and to secure the greatest efficiency he should have a voice in the appointment of his subordinates as well as the power to recommend discharge after proper hearing, for efficiency cannot be secured without discipline by a single responsible head. With such an organization the economy in conducting the work will be improved from year to year; efficiency without economy is impossible. Many policies have been settled by experience, and most of them have been put in print, but there remains much that is experimental, and the solution of many problems must be left to the ingenuity of the superintendent as they arise. For instance, while the efficiency of the cast-iron mains has been pretty thoroughly tested with most waters, the life and coatings of steel mains are still problematical. The size of mains necessary in certain places offers a wide field for ingenuity and thought on the part of the superintendent; so with the service pipe; except in special qualities of water, lead is almost universally used, yet the regulation of the size is subject

to wide variation dependent on the pressure and quantity of water necessary or desirable to be supplied in a given time, and the regulation of the size calls for even more consideration than the size of the mains, for the theory that a certain quantity of water will go through a certain sized hole regardless of the length of the pipe is one of the most common errors of the ignorant and unthinking.

I believe no one has yet discovered the best water meter, yet there is a chance to exercise considerable judgment of the kind or type for different circumstances or uses, and if the board of managers insist on selecting the cheapest without regard to material or construction, the result will be disastrous to the efficiency of the meter department.

The conclusions of sanitary experts are changing every minute and the superintendent must have a very logical mind to separate the theoretical from the practical.

What about the composition of the board of directors? The corner grocery or professional politics do not usually fit men for undertaking large affairs, and a man who never handled a hundred dollars in his life is somewhat bewildered when given $100 000 to spend. Some men are so constituted that they magnify a dollar to cartwheel size; others have so little knowledge of its value, especially when it belongs to some one else, as to ignore its size altogether. The first, while saving cents, will lose dollars, and the second will lose both. The best proof of a man's ability to manage large undertakings for other people is that he has managed his own large business successfully. A board of managers, for instance, when buying land or rights, may in their effort to drive a sharp bargain overreach and get into a lawsuit which will cost many times the amount saved. Another board may saddle the city or company with a filter or an expensive reservoir unnecessary for the time being at least.

In construction or extension of the work where it is necessary to engage a designing engineer, the superintendent may give advice which should always be given consideration. For the design of work is one thing and the care of it another. Many a superintendent has been worried into the grave trying to adapt an impractical scheme designed by an engineer without experience in management.

The board when selecting its designing or consulting engineer might remember that a six weeks' trip to Europe does not make an engineer, and might well consider if an expensive filter or massive dam is necessary. The interest account of many a city or company is burdened with the cost of an extravagant structure built but to gratify the fad of the designing engineer.

A celebrated foreign engineer on viewing a large water-works dam once said that "any fool could build a dam if he could use a large enough factor of safety."

It should be borne in mind that every gallon of water has a fixed value and that that value is dependent on the cost and capacity of the work and the expense of maintaining it. No work can be run efficiently until this fact is recognized and understood. If the rates are so regulated that one man gets two gallons for the price of one, then the man who uses one gallon and pays for it pays part of the other man's water rate.

The cost of the water system and its maintenance should be borne by the consumer of water and, except as to that part of the expenditure necessary for the extinguishment of fires, in proportion to the amount of water used.

The practice of furnishing water free to the city departments, hospitals, and other institutions which may make a plausible plea to the board, as well as the practice of furnishing extra fire protection free to certain parties who are patrons of certain insurance companies, is not only unjust to the rate payers, but makes a statement of the measure of efficiency impossible.

If it is thought necessary to lay out a park or pleasure ground on lands controlled by a public water department, why not charge it to the park department? What has tree culture to do with the conduct of a water system?

Many cities have tons of lead service pipe where they will never be used, laid with the expectation of preventing the disturbance of the pavement which other public service corporations dig up without hindrance. It has become necessary in one large city to expose the mains and shut off these unused extra service pipes to prevent leakage.

Few water departments make any account of water furnished to other city departments, and, on the other hand, few water depart-

ments make remuneration for damage to streets. A precise system of accounting would stop many leaks in a water-works system. In fact, it is usually impossible to tell whether the works are efficiently managed or not from the published accounts. A balance sheet is of rare occurrence in a water report, and an inventory or any charge for depreciation still more rare.

The president of one water company furnishes all water pipe used, and a relative furnishes all coal, without competition; the water taker pays for both, in high rates. The superintendent has been dismissed, being of a too prying disposition. Another water company has all outside work done by a relative of the president on a percentage. What is more common than for one member of the board to interfere with details of the management of a department? — and the more ignorant he is the more likely he is to interfere.

Of what use is a meter system when 30 per cent. of the water is wasted by poorly jointed pipe and 20 per cent. by the waste in public buildings?

Efficiency can only be effected by order and system coming through one responsible head, and that head must be more or less of an autocrat, each subordinate being in turn responsible to the one above.

In this age when improvements in methods and means of transacting business are constantly being introduced, it requires constant study and clear discernment to find and apply the device or method necessary for the particular work.

In a city of considerable size it is impossible for the superintendent to observe every detail of the work, and he will accomplish more in his office than in his automobile, but he must first acquire a knowledge of the work and his subordinates by observation. At his desk he decides a multitude of problems, from the color of paint to quality of yarning, from the probable registry of an obstructed meter to the efficiency of his pumps; and all the time he must know what each subordinate is doing and what he is going to do the next day.

This in general is an outline of some of the things necessary to have and a few of the things to avoid in an efficient water-works system, and the efficiency is measured by the cost of the water

supplied, taking into consideration its quantity and the necessary expense to secure and distribute it.

As mentioned above, the time is fast approaching when the constantly increasing indebtedness of water supply systems will attract the public attention and managers will be held strictly accountable to the public. Until that time comes, the following description of the water-works superintendent by President Alvord, of the American Water Works Association, will hold good: "He has held out to him no alluring pension as a reward for the honest, faithful, and nerve-racking care and service he gives, but is haunted day and night by fear of a broken main, failure of water supply, or of disease traceable to the water. He has trouble securing funds for procuring the necessary equipment, and, above all, has to deal, always courteously but firmly, with the ever-present infuriated citizen who insists he is not getting his just dues from a government he helps support."

How can efficiency be best promoted? I should say by system carefully thought out, by having order everywhere, and by well-defined rules thoroughly and impartially enforced.

DISCUSSION.

Mr. A. E. Martin. Mr. President, I presume that every one here who has anything to do with water works in Massachusetts has felt the effect of the eight-hour law, so-called, and I think we will feel it more as time goes on. The chances are that some of us may find ourselves up against a one thousand dollar fine and imprisonment for six months, more or less, if the judge who has the case to try happens to be one of our disappointed customers. I think it is going to be a pretty hard problem to do our work in eight hours a day, or forty-eight hours a week, and make the system as efficient as it ought to be.

The rule I propose to adopt, as far as I can, is this: That my first duty is to see that every customer gets his water when he wants it, and when he ought to have it, and if I have to infringe the law to do that, some one will have to back me up. It would not take many one thousand dollar fines to eat up my yearly

salary, and my family would feel its effects, if I had more than one such fine to pay in the course of the year.

Mr. Richards. What Mr. Martin has said with regard to the eight-hour law puts me in mind of something which I should have mentioned, perhaps, in my paper. It is a question whether a man can accomplish as much work in nine hours as he can in ten, provided the men working with him are equally efficient; but you have got to have a limit somewhere, of course, and when you put it at eight hours I doubt if it holds true. I do think, however, that in nine hours an ordinary man, if he is efficient, will do about as much work as he would in ten. I have just been notified by a walking delegate that my men must work only eight hours, so I am beginning to think over the question myself a little.

Mr. Martin. Mr. President, it has just been suggested to me that some of our members, who are not Massachusetts men, may not know exactly what the Massachusetts eight-hour law means. For their information I might say that during the past four years there has been a constant effort made to secure the passage of a law whereby no municipal employee should be *allowed* to work over eight hours in any one day, or forty-eight hours in a week. Such a law was passed by the legislature and twice vetoed by Governor Draper, but this year it has been signed by Governor Foss, after a certain feature had been eliminated by the Supreme Court. As the law now stands, if a man by working a little overtime has any extra time to his credit at the end of the week, so that, for instance, he has worked forty-eight hours in five days, he *must* lay off the remainder of the week. The penalty for each infringement of the law is a fine of one thousand dollars, or imprisonment for six months in jail, or both. That applies to the man who is responsible, and is supposed to be the superintendent.

It strikes me that the various water boards will have to stand in the breach and back us up, for I don't think there are many superintendents who would care to spend six months in jail or even pay a fine of one thousand dollars. But that is what we are up against now. I think perhaps if municipal officials had realized as much about it before the law was passed as they do now, they might have appeared at the State House and attempted to prevent the passage of the bill, although I hardly believe they would have been suc-

cessful. The movement has been under way three or four years, and the labor men were bound to put it through, and now they have got the law I doubt if it will ever be repealed. It may prove to be unconstitutional, and I believe it will, if a test case is ever brought, but I don't know of anybody who wants to stand up and test it. I certainly do not, for one.

Mr. A. L. Sawyer. Don't you understand that in cases of emergency the men can work overtime?

Mr. Martin. Yes. In the case of an emergency, when there is a break or anything of that kind, which is going to cut off the water supply, we are allowed to work overtime.

Mr. Sawyer. In Haverhill our superintendent is striving to keep within the law as well as he can, and in case of a break that has to be attended to he keeps on file a separate record of it, under the head of "Emergency Work," and that will be open to the state police inspectors. I doubt if the inspectors will get around very often, for this is a big state for them to cover.

Mr. Martin. I will say in answer to Mr. Sawyer that I do not think it is the state police who are going to interfere with us as much as it is the agents of the labor unions, and those people who used to be called "walking delegates."

Mr. Sawyer. The foreman of our street department has told me that the men in the street department in Haverhill are against the law.

Mr. T. J. Carmody. I think, Mr. President, that Mr. Martin is wrong in his interpretation of the law. If a question of the public health is involved, you can work the men over forty-eight hours, and I think myself the law is a good one. I am in favor of it, because I think there are a good many men employed in the departments who, without such a law, would have to work a good deal overtime. If a man works forty-eight hours a week, working day or night, I don't see why he shouldn't then be entitled to lay off. I think eight hours a day is long enough for any man to work, and I think he can really accomplish as much in eight hours as he can in nine. A man can do but a certain amount of work anyway, and my experience in my own line of business has been that a man can do just as much in eight hours as when he was working nine or working ten hours.

Mr. Arthur A. Reimer. The paper presents a subject that I think we all have studied more or less unconsciously, that is, without calling it "Efficiency in Water-Works Management." I think we all, as men interested in some line of endeavor, be it the management of a water plant or the designing of some engineering structure, strive to get the best results possible, if we are true to our calling; and, therefore, we are efficiency students to that extent, though we may not apply that particular term to it.

The author stated that eventually the measure of efficiency is going to be cost. I could not fully agree with that statement, for, without knowing that others were going to mention this eight-hour matter, I had in mind several elements, one of which was this very question of the eight-hour law. A man who is working under the stress of a definite law with an eight-hour limit certainly cannot compare his work and the results accomplished with the work done by another man working under no restriction as to time and working the usual and customary term of ten hours with his men. I think some other standard of comparison will have to be used than the standard of cost. We must measure the results accomplished by some other element than the financial one. I am not overlooking the fact that local conditions produce very different results and costs in different localities, but the cost is not necessarily the proper basis of comparison of efficiency, even when an analysis includes the effect of local conditions.

I agree fully with the position the author has taken with regard to the attitude which should be assumed by the head of the department. The author used the term "autocrat," and I do not believe that a better term can be used to describe the position which should be occupied by such a man when it comes to the question of the employment and discharge of men occupying positions under him or the executive management of the department. If we are to be held responsible for results accomplished in our departments, and I think we all regard our department as ours, and if we have the interest of the department at heart, we certainly should have full control of the department. Responsibility without authority is as bad a condition as taxation without representation.

I think that is the attitude that we all should seek to occupy

with regard to the management of the various departments. I cannot speak about the private companies, because I have never had any connection with one of them, but certainly in municipal work, where politics enters to such an extent, if we are going to get good results I believe it is our duty to stand firm and say that we must have full power. If we cannot I am afraid it will be a case of wreck the department or resign. The commission idea that is sweeping the country at present, and is so much talked of, has as one of its basic principles the fixing of individual responsibility, and that same principle applied to the water department means that the superintendent or engineer, or whatever his title may be, must be the executive power in that department, although of course the governmental work, when it comes to laws and so on, must be carried on by the City Council, or the Commission, or whatever body it may be that is the administrative head of the city.

We are troubled with the eight-hour law down in New Jersey. It has come to us this year as an unwelcome present. We are allowed to work the men overtime in case of emergency, but they have to be paid for it. To meet the situation in our department I told the various foremen and assistants that I wanted them to endeavor to get as much work done in the eight hours as they had formerly in ten. I said that was what they should strive for; I did not tell them they would have to get it, for I did not know that it would be possible. I have been interested in comparing the results during the past few months with the results accomplished under the old ten-hour rule, and I find that by constant prodding of the foremen, they can get nearly as much work done with their gangs in eight hours as they formerly did in ten, and I should be glad to hear what others have been able to do along this line. We have not worked under the eight-hour law for a full year yet, so I cannot give a year's results, but at present we are getting along fairly well under the eight-hour rule. It means, of course, that the foremen are working up to a higher standard of efficiency, that is what it comes down to, because they are using their brains to devise schemes to save work which was formerly done, perhaps uselessly, and the department would, therefore, seem to be working on a higher plane of efficiency on

the labor end. But other features of the eight-hour law make it highly objectionable, and largely, if not fully, offset any advantages that may come from it.

Mr. M. N. Baker. It seems to me that attention should be given to a functional classification of water-works administration with a view to working out a basis of cost of service. Such statistics as have been compiled in the past have been largely valueless because they do not get down to the bottom facts which should govern and instruct a water-works superintendent. It is earnestly to be desired that all water-works men should join together in working out some better forms. Just how this can be done is too large a question to enter upon at this time; possibly it might be worthy of consideration by a committee of the Association at some future date.

Mr. W. C. Hawley. I am particularly interested in this eight-hour proposition, Mr. President. If the time which the superintendent has to spend in Massachusetts measures up with what the superintendents elsewhere have to spend, I can see where he will have Saturday and possibly Friday and maybe some of Thursday off most every week. I think I will apply for a position in Massachusetts.

In addition to the qualifications of a manager, which Mr. Richards has mentioned, I think he ought also to be something of a lawyer. I have found in connection with municipal plants that you cannot always depend upon the political lawyers who are connected with the city government, and have found in connection with privately owned plants that a good many questions come up which must be decided when there is no time for consultation with an attorney.

This matter of efficiency is one which is receiving a great deal of attention, and one which needs to be considered in the waterworks business, especially in municipally owned plants. I think that as a rule the privately owned plants, the larger ones at any rate, have been obliged to give a great deal of attention to the subject; but such investigations as I have made as to municipally owned plants show a large mixture of politics with business, and generally not for the good of the plant.

Incidentally, there is much that we water-works men can learn

from the decisions of the Wisconsin Railroad Commission in the carrying out of the Public Utility Law of the State of Wisconsin. The work which has been done by that board in analyzing the costs of plants and the costs of the different kinds of service has been very interesting, instructive, and helpful. The decisions have certainly surprised those municipalities that have come in contact with the law. This is especially true in the case of the municipal plant of the city of Madison, and also in the case of the City of Beloit *v.* The Beloit Water, Gas, and Electric Company. A summary of this latter decision was published in the *Engineering Record* of September 2. These municipalities have been surprised to learn what it costs to furnish fire protection. The water companies have had this matter forced upon their attention because so few of them receive anything like an adequate return for the furnishing of fire protection and water for other municipal uses. In nearly every case they have been obliged to charge a rate for domestic service which would cover part of the cost and, generally, a large part of the cost of furnishing water for fire protection and other municipal purposes and to get from the municipalities what they can for these services. In both the Madison and Beloit cases, the Wisconsin Commission decided that very much less than the proper amount for furnishing fire protection had been allowed and that when a proper charge for those services had been made the rates for domestic service should be materially reduced.

Mr. Baker. It happens that only yesterday I was talking with the chief engineer of the Wisconsin Railroad Commission, and what he had to say, with what had already come to my attention, bears out the statement of the last speaker to the effect that the work of that commission is well worthy of the study of all water-works men. The commission are entering upon their work with zeal and with an unusual degree of wisdom, and trying to get to the bottom of the various problems which they are called upon to solve, and to do it in a way, as it should of course be done, which will be for the interest of the people who are being served by the public service corporations, and who are being served by the municipalities, for they have control of the municipally owned plants as well as of the privately owned plants.

Mr. George A. King. Mr. President, there is one thing which

Mr. Richards suggested which, it seems to me, is worthy of considerable thought, and it is right along the line which men are employing in other work, — that is, that a carefully thought-out plan in the office is of great value in reducing the cost of work. I think we ought to give a great deal more thought to the matter of designing work in the office and laying out our plans there, and by doing that we can save money.

Mr. Richards. As to the standard of cost, of course the cost of one hundred per cent. of efficiency must be different in every work, because it will be governed by different things, such as the remoteness or nearness of the source of supply, whether the water is pumped or not, and so on; and there are so many variations that each individual plant must be judged by itself. The basis of one hundred per cent. is different in each case, and hence the cost per gallon must be different in each case: and the fallacy of comparing the water rate in one town with the water rate in another is apparent, when we come to think of it.

I fully agree with Mr. Hawley in what he said about law; but, after all, law is simply good horse sense, when you come right down to it, and you can't have efficiency without horse sense.

I meant to have referred to the Wisconsin Commission, because what extracts I have seen from their decisions have been of immense help to me, and have put any quantity of ideas into my head. I don't know but what the records of the Wisconsin Commission would come next to the Journal of the New England Water Works Association in value.

The President. I saw some doubt expressed in the faces of the members when you stated your proposition, Mr. Richards, that law is nothing but horse sense.

Mr. Richards. Perhaps I ought to have said "justice."

The President. I think that amendment will be accepted.

Mr. Frank L. Fuller. Referring again for a moment to the eight-hour law, I wonder if anybody can tell by the activity which they display, when he sees men at work, whether they are working eight hours a day or whether they are working nine hours? It seems to me that eight hours is a pretty short day for men to work in water-works construction. There are a great many things to get ready and plan out, and the eight hours is up almost, —

I wouldn't say before you get started, but it is a pretty short day.

Mr. Richards. I think I am in favor of an eight-hour law for the superintendents, and it occurs to me that it might be worked out in this way: You could have three superintendents and they could each go on duty for four hours. That would be very easy. The salary would of course remain the same.

Mr. Martin. That is the point I thought of when Mr. Carmody suggested that forty-eight hours a week was enough. I think forty-eight hours a week *is* enough for the laboring man; eight hours a day *is* enough for the ordinary working day. But when it comes to the superintendent, or the man in charge, what about him? Does he work forty-eight hours a week, or does he work twenty-four hours a day? I have been employed in this kind of work for upwards of thirty years, and I never yet have felt that my day's work was done when I went home at night. I have never felt like going out of town unless I could leave somebody to look after my work while I was away. The work of the water department is going on day and night, twenty-four hours out of the twenty-four, and the superintendent has it on his mind all the time. It is not merely eight hours a day for him, but he is on duty the whole twenty-four. I think eight hours a day is enough for a regular day's labor, but when it says that a man shall not be *allowed* to work occasionally ten hours a day if he wants to, and make a little more money by it, I think the law is going beyond its province in denying a man that privilege.

Mr. W. H. Richards (*by letter*). Any increase in efficiency must finally in the long run result in a saving, either a saving in maintenance, reduction in first cost, or a reduction in liability to excessive cost. Take, for instance, a dam; if built of excessive strength at excessive cost, the interest on that excessive cost must be paid forever. On the other hand, if weakly constructed, to save money, it finally goes down, causing great damage and great cost. It is apparent that it lacks efficiency in both cases. Again, if a pipe system is so constructed as to reduce the cost of repairs per mile below the average, the efficiency of the works is increased and that efficiency is measured by the reduction in the cost of repairs.

An elaborate system of locating mains and other underground

fixtures may require a considerable expenditure of time and thought, and will surely result after a time in the saving of money.

And so it will be found on careful analysis that efficiency or lack of efficiency can always be reduced to dollars and cents.

A SHORT ACCOUNT OF SOME PURIFICATION EXPERIMENTS WITH A SURFACE WATER IN QUEENSLAND, AUSTRALIA.

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[*Read September 14, 1911.*]

The following is a short account of some experiments conducted by the writer on behalf of the Brisbane Board of Water Works in order to determine the best practical method of purifying the Enoggera Reservoir, one of that city's sources of supply.

These experiments were conducted over a period of four years from 1904 to 1908. Unfortunately, many of the data accumulated during this period are not, at the moment of writing, available to the author, but there are sufficient to cover the principal features of the experiments.

The Enoggera Reservoir, which has a capacity of about 1 000 million gallons, contains surface water collected over a catchment area of 12.9 square miles, which is for the most part fairly heavily timbered with eucalyptus, with a large proportion of a comparatively dense undergrowth.

This area is under the control of the board, there are no human habitations permitted on the watershed, and it is also patrolled, so that there is, practically speaking, no danger of bacterial contamination. The objectionable quality of the water is due to the presence of tastes, odors, and ferrous iron in the water reaching the consumer.

The quality of this supply has been a source of reproach to the city almost ever since its inception and the Board of Water Works have obtained many reports and have conducted many series of experiments with the object of ascertaining some practical method of rendering it more suitable for a town supply.

The following table will serve to give some idea of the atmospheric temperature at the reservoir throughout an average year,

the figures quoted being those for the year 1906, the last year for which the writer has an available record.

Average Daily Mean Shade Temperatures at Filters in 1906.
Degrees Fahrenheit.

January	77.7
February	76.0
March	72.7
April	70.6
May	63.5
June	58.4
July	54.8
August	58.4
September	60.1
October	67.5
November	72.0
December	74.0

The experimental filters used in the investigation under discussion were situated close to the reservoir, so that the above table also serves to indicate the conditions at the filter site.

The reservoir contains very heavy growths of fresh-water plants, water lilies, Myriophyllum, Ceratophyllum, etc., and there is a considerable accumulation of organic matter in the silt at the bottom.

There is only one overturning of the reservoir contents during the year, occurring about the month of May. This is due to the fact that the temperature of the water is never low enough to reach the point where water attains maximum density, which phenomenon in a less mild climate is the cause of a second overturning. As a consequence, the water is stagnant at depths below 19 ft. for eleven months out of the twelve, and these conditions are very favorable to putrefactive processes. Thus, from a depth of 20 ft. downwards, the water, except during the annual overturning, contains little to no oxygen and the iron contents show a corresponding increase. At 20 ft. from the bottom, at a place where the reservoir had a depth of 60 ft., the data at hand indicate iron in solution to as much as 50 parts per million.

The comparatively high and long-continued summer temperatures, the large proportion of shallows in the reservoir, the long stagnation period, strong light, and high organic content of the

water are all in favor of an abundant growth of algæ, especially the bluegreens, with their accompaniment of disagreeable odors and tastes, and this growth indeed takes place. Clathrocystis grows most abundantly, while Anabæna and Oscillaria are also often plentiful. Synedra sometimes occurs in such quantity as to render the surface water quite opalescent, and Peridinium is also frequently present in large numbers. The water has nearly always a moderately offensive odor, not always so noticeable at the reservoir itself, but more so at the consumer's end of the pipe. The trouble is augmented by growths of Plumatella, Cordylophora, and Sponge in the mains.

Plumatella grows very densely in the pipes at the inlets to the service mains, and in the autumn, when it usually begins to decay, it becomes detached from the pipes and disintegrates, thus causing much additional trouble in the shape of a new variety of offensive odors and mechanical obstruction to faucets, meters, etc.

The composition of the reservoir water is given in Table 1, containing analytical results obtained during the year 1906. The samples for analysis were collected during a period of one hour at the inlets to the various experimental filters, the idea being to obtain a fair average sample of the water applied to all the filters.

This water was drawn through a short length, about 100 yd. of 16-in. cast-iron main, collecting water from a depth of 5 ft. below the surface of the reservoir at a point about 60 yd. from the bank in the deepest portion of the reservoir. In this table, as well as in the other tables of analyses to follow, the methods used were, with one or two exceptions, those recommended by the American Committee on Standard Methods of Water Analysis.

As already indicated, and as is usual with waters of this type, the main object sought to be attained by purification of the water, was the removal of tastes, odors, color, and iron. To this end many types of filters and processes were tried. It would be tedious and unprofitable to describe in detail all these processes, and it will suffice to survey briefly the results obtained by the more important ones.

The first experiments with which the writer was concerned were with coagulants and rapid filtration. Alum and lime were the coagulants used, and the rate of filtration varied up to 130

TABLE 1.

Enoggera Reservoir Water drawn Five Feet below Surface.

Monthly Averages of Analyses.

Month. 1906.	Number of Determinations (except where otherwise shown in parentheses).	Temperature of Water at Time of Collecting Sample.	Parts per Million. Ammonia. Free.	Ammonia. Albuminoid.	Oxygen Consumed at 90° F. 15 minutes.	Oxygen Consumed at 90° F. 4 hours.	Total Iron.	Chlorine (Cl).	Alkalinity (as $CaCO_3$).	Free Carbonic Acid (CO_2).	Color. (Platinum Scale.)	Dissolved Oxygen.	Bacteria per c.c. Incubated 48 Hours. 98° F. Neutral Agar.	68° F. Neutral Gelatine.	Odor (Cold).
January......	8	79.8	.05	.35	2.6	4.5	.22	35	38 (7)	....	49*	6.2 (5)	1230 (2)	......	Strong vegetable.
February.....	7	79.9	.05	.33	2.5	4.4	.23	35	38	....	52*	5.9 (3)	325 (1)	......	Strong vegetable.
March........	1	76.5	.06	.34	2.8	4.6	.40	34	24	3.5	67*	......	......	......	Very strong vegetable.
April.........	3	76.0	.04	.25	2.5	4.5	.29	32(2)	27	2.9	51*	......	......	......	Strong vegetable.
May..........	3	67.8	.05	.21	2.3	4.2	.65	29(2)	29	8.3	80*	......	......	......	Strong vegetable.
June.........	4	63.4	.06	.25	2.1	4.0	.56	28	28	3.0	51*	6.9 (2)	150 (2)	800 (1)	Distinct and nil.
July..........	5	59.4	.04	.28	2.0	3.9	.47	28	29	2.2	44*	8.8 (4)	605 (2)	987 (2)	Nil.
August.......	4	60.7	.04	.31	1.9	3.8	.41	29	30	3.0	35*	9.0 (2)	350 (2)	......	Slight.
September....	2	66.7	.02	.31	1.8	4.0	.41	29	29	3.7	32 (1)	......	......	......	Slight and distinct.
October.......	5	74.3	.02	.27	1.8	3.4	.37	27	30	4.8	32	7.0 (1)	325 (1)	......	Distinct.
November.....	4	77.6	.04	.24	1.6	3.2	.31	30	32	3.2	23	6.7 (2)	......	......	Distinct.
December.....	2	80.5	.05	.29	1.7	3.5	.41	32	31	2.6	22 (1)	......	......	......	Distinct and strong.

* Up to the month of July, 1906, color was determined by means of the Lovibond tintometer; afterwards, by comparison with platinum cobalt standards. It was found, however, by means of parallel observations, that a simple computation would, with considerable accuracy, convert the Lovibond units into parts per million on the platinum scale. For the sake of easier comparison this has been done in the above table.

million U. S. gallons per acre per day. The experiments were arranged and supervised by the government analyst, Mr. J. B. Henderson, who reported favorably on the results obtained.

Records as to the removal of odors were, unfortunately, not made; to the best recollection of the writer it was not always quite complete, though very satisfactory reductions of organic matter and color were effected. The board, however, was evidently not thoroughly convinced by this report, probably owing to the suspicion with which the use of coagulants is, or was, regarded by British communities, and a further series of experiments was inaugurated, for the supervision of which the writer was employed by them.

The following were the principal methods of purification experimented with: A filter called by us the "Morry" filter, after its designer, Mr. C. A. Morry, an official of the Department of Public Works in Brisbane; a combination of sand filtration and the Morry filter; ordinary slow continuous sand filtration; the Anderson revolving purifier process; aëration and filtration of the bottom water from the reservoir; and slow intermittent sand filtration.

Several varieties of Morry filters were tested. The main principle of this filter is that of the Ducat bed for sewage treatment. The following description of a typical Morry filter will suffice to show the general arrangement. Other forms varied from this in the size of filtering material, and in some of them sand and even small coal were used.

The filter is constructed with walls of dry stonework within a timber frame on a square plan, and has an internal diameter of 9 ft. 4 in. at the bottom and 8 ft. 2 in. at the top.

The walls rest upon a concrete bed dished towards the sides, which forms the bottom of the filter and serves to conduct the effluent into a concrete channel which constitutes the discharge.

The filtering material consists of 6 ft. 6 in. in depth of screened gravel, a rough mechanical analysis of which gives:

100	per	cent.	finer	than	8.5	millimeters.
51	,,	,,	,,	,,	6.0	,,
23	,,	,,	,,	,,	4.0	,,

TABLE 2.

MORRY FILTER NO. 1 (ALL GRAVEL).

Composition of Effluents. Monthly Average for 1906.

	Determinations.[1]	Rate Filtration U. S. Million Gals. per Acre Daily.	Parts per Million. Ammonia. Free.	Ammonia. Albuminoid.	Oxygen Consumed at 90° F. 15 Minutes.	Oxygen Consumed at 90° F. 4 Hours.	Total Iron.	Free Carbonic Acid.	Nitrogen as Nitrates.	Color. (Platinum Scale.[2])	Dissolved Oxygen.	Turbidity. (All under 5 p.p.m. in Silica Scale.)	Bacteria per c.c. Incubated 48 Hours. 98° F. Neutral Agar.	Bacteria per c.c. Incubated 48 Hours. 68° F. Neutral Gelatine.	Odor (Cold).
January	8	2.3	.02	.13	1.4	2.4	.09(7)	.....	.08	18	7.1 (4)	Slight.	57 (2)	......	Fifty-seven de-
February	7	2.4	.01	.13	1.5	2.6	.12	.....	.10	20	8.0 (3)	,,	50 (1)	......	terminations
March	1	2.9	Tr.	.17	2.1	3.4	.14	.88	.03	36	......	,,	......	......	gave the fol-
April	3	3.1	.02	.15	1.8	3.2	.15	1.2	.13	30	......	,,	......	......	lowing:
May	3	2.9	.01	.13	1.6	3.0	.03	1.3	.08	34	......	,,	......	......	Nil, 44
June	4	3.0	.02	.14	1.5	2.9	.03	1.2	.17	25	10.0	,,	......	......	Slt. tr., 4
July	5	2.6	.01	.17	1.5	2.8	.02	1.1	.09	23	10.2	,,	18 (2)	110 (1)	Trace, 9
August	4	2.3	.01	.17	1.3	2.5	.14	1.2	.10	18 (2)	9.7	,,	92 (2)	180 (2)	
September	2	2.4	.02	.18	1.3	2.5	.14	0.9	.15	20	......	,,	50 (2)	......	
October	5	2.8	.02	.16	1.2	2.1	.15	1.0 (4)	.17	13	8.8	Trace.	......	......	
November	4	2.5	.02	.16	1.1	2.3	.25	0.9	.07	13	8.7	,,	......	......	
December	1	2.9	.01	.17	1.0	2.0	.22	.....	.20	13	......	,,	......	......	

[1] The figures in parentheses denote the number of determinations in the special cases.

[2] Except during the months of August and September, the color of this effluent was determined by the Lovibond tintometer. The figures given for the other months have been computed from the Lovibond units.

Water is fed on to the filter bed through an intermitter of 20 gal. capacity, from which it is discharged automatically by means of a siphon, at intervals, into the hopper of a revolving sprinkler which distributes it evenly over the bed, through which it slowly percolates. Provision is also made for side aëration, in addition to that derived from the loose stone walls, by means of four lines of loosely jointed unglazed earthenware pipes placed within the filtering material and traversing the bed from wall to wall. During the time this filter was at work, over six years, nothing was done to the filtering material except to rake the surface at long intervals in order to bring it to a level.

The color reduction effected by this filter (Table 2) was not good and odors occasionally appeared in the effluent. It is evident that the material of which the bed is composed was too coarse to permit of efficient filtration, but it was thought that a filter of this type might give good results if used as a roughing filter in conjunction with an ordinary continuous sand filter. This was duly tested. Very excellent results were obtained with the combination. It was found that odors and tastes were effectually removed when working

TABLE 3.

Average Composition of Effluents from and Percentage Reduction effected by Morry Filter No. 3A, used as a "Roughing Filter."

	Fifty-Seven Determinations made during the Period 3d Oct. to 31st March, 1907. Average Rate of Filtration, 8.44 Million U. S. Gal. per Acre per Day.		Four Determinations made during the Period 1st to 24th April, 1907. Average Rate of Filtration, 17.8 Million U. S. Gal. per Acre per Day.	
	Parts per Million.	Per Cent. Reduction.	Parts per Million.	Per Cent. Reduction.
Free ammonia	.01	65	.01	73
Albuminoid ammonia	.20	30	.20	25
Oxygen consumed in 15 min.	1.7	18	1.2	15
Oxygen consumed in 4 hr.	3.0	21	2.4	17
Iron (total)	.23	38	.27	35
Dissolved oxygen	8.2	..	..	..
Turbidity	slight	..	slight trace	..
Color (platinum scale)*	25	39	15	42

*The figures for color were obtained by computation from Lovibond tintometer "units" estimated in the Lovibond tintometer.

at a combined rate of 6.0 million U. S. gallons per acre per twenty-four hours. The Morry filter used was similar in design to that already described, but the bed of the filter was only 3 ft. deep. The sand filter used contained 3 ft. of Brisbane River sand, having an effective size of 0.28 mm. and a uniformity co-efficient of 1.96.

Tables 3 and 4 give the results obtained over an extended period.

Sixty-one observations of odor in the cold made during the above period gave the following:

Nil	14
Slight trace	12
Trace	7
Slight	19
Distinct	9

TABLE 4.

AVERAGE COMPOSITION OF EFFLUENTS FROM AND PERCENTAGE REDUCTION EFFECTED BY THE COMBINATION OF MORRY FILTER NO. 3A AND A SAND FILTER.

	Thirty-Eight Determinations during the Period March, 1906, to March, 1907. Average Rate of Filtration for the Combination, 2.93 Million U.S. Gal. per Acre per Day.		Four Determinations made during the Period 1st to 24th April, 1907. Average Rate of Filtration for the Combination, 6.0 Million U. S. Gal. per Acre per Day.	
	Parts per Million.	Per Cent. Reduction.	Parts per Million.	Per Cent. Reduction.
Free ammonia	.01	69	.01	76
Albuminoid ammonia	.12	54	.11	56
Oxygen consumed in 15 min.	1.3	31	1.0	27
Oxygen consumed in 4 hr.	2.3	34	2.0	33
Iron (total)	.12	68	.11	73
Dissolved oxygen	7.6	..	..	..
Turbidity	nil	..	nil	..
Color (platinum scale)*	13.0	54	9.0	70
Odor	nil	..	nil	..

*The figures for color were obtained by computation from Lovibond tintometer "units" estimated in the Lovibond tintometer.

Several sand filters of the ordinary slow continuous forms were tested. These, while giving very good and fairly uniform results, showed some slightly objectionable features and did not compare

favorably in their efficiency as regards removal of odors and tastes, with the combination of gravel bed and sand filter just mentioned, nor with the intermittent filter to be described later.

During the warmer months of the year, on account of the increased biological activity occasioned by higher temperatures, it was found that the oxygen dissolved in the water applied to the sand filters was often nearly and sometimes quite exhausted in passage through the sand bed. With the object of improving this condition aërators were fixed at the inlets to the sand filters. These aërators effected an almost complete saturation of the applied water in which the oxygen content was increased from about 75 per cent. to 98 per cent. of the possible amount.

Notwithstanding this, the oxygen still continued to be almost entirely exhausted in passage through the filters, though a slight increase in the oxygen content of the effluents did actually take place after installation of aërators at the inlets.

It seemed at first glance that this was unimportant as the aëration of purified water is a simple matter, but the writer was impressed with the fact that, as the using up of the oxygen indicates a corresponding oxidation of organic matter, which was the main object of our process, the fact that all oxygen was used up tended to show that greater oxidation might possibly be effected if more oxygen could be supplied to the bacteria doing the work. In the case of the Morry filters this was supplied by the method of application and the construction of the filter, and the effluents were never found lacking in dissolved oxygen; but these filters failed in other respects. These considerations led to the trial of intermittent sand beds.

It may be of interest to mention briefly the results of experiments with the Anderson Revolving Purifier Process which is successfully used for waters of this type in some British colonies. It is unnecessary to describe the process, which is well known and consists essentially in the solution of iron by the water, effected by passing it through a revolving drum which showers scrap iron continuously across the current, and the subsequent oxidation and precipitation of the iron. The ferric hydrate formed acts as a coagulant and the water is subsequently filtered. It was found

that under practicable conditions the process gave no results comparable with sand filtration *per se*, but that, when the iron dissolved in the purifier amounted to as much as 80 parts per million, the effluent produced by the filter working at a rate of over 6 million U. S. gallons per acre per day was of very exceptional quality, a removal of about 80 per cent. of organic matter expressed as albuminoid ammonia and oxygen consumed and about 90 per cent. of color being effected. This is a far better result than was obtained by any other process, but the method is, of course, quite impracticable on account of cost.

In January, 1907, it was suggested by Mr. Allen Hazen that aëration and filtration of the bottom water from the reservoir might give good results, and experiments in this connection were immediately undertaken. The bottom water for the greater portion of the year is, as a result of stagnation, very much more highly colored and contains much more organic matter and iron than the surface water. It was thought that, on account of the large amount of iron and the condition of the organic constituents, which is one of partial putrefaction, that the water after aëration and sedimentation would be readily amenable to the ordinary methods of filtration, and also that filtration, if combined with sedimentation, could be safely carried out at a far greater rate than usual on account of the presence of ferric hydrate in suspension, which would act as a coagulant much in the same manner as it does in the Anderson process just mentioned. It was found that, with liberal aëration and forty-eight hours' settlement previous to filtration, it was possible sometimes to get a very satisfactory filtrate and at a rate of 6 million U. S. gallons per acre per day, but the results were subject to considerable fluctuation and, usually, the filtrate contained considerable color and iron. It was found most difficult to secure a complete precipitation of iron hydrate, which was possibly suspended in a colloidal condition. The writer is by no means convinced, however, that, in the light of recent scientific research on the subject of the precipitation of colloids, this ingenious method of utilizing the coagulant provided by nature could not be successfully carried out.

One other process tried remains to be mentioned, namely, slow intermittent filtration through sand. The considerations which

led to the trial of this process have already been mentioned under the head of "continuous filters."

The principle is essentially the same as that used in the Morry gravel filters, the main differences being in the size of the filtering material used and in the mechanical details connected with the distribution of water over the filter bed.

It was expected that the additional oxygen supplied for the oxidation processes by the intermittent application of water to the sand bed would result in an increased oxidation of the dissolved organic matter with a more complete removal of iron, tastes, and odors. The results indicate that, through this method of operation, an increased amount of oxygen is undoubtedly supplied to the water in the sand bed, as the effluents always contained a considerable quantity. An increased oxidation of organic matter also takes place, though this is indeed quite slight.

The most satisfactory improvement is in the matter of removal of odors; this was most complete, as only on very rare occasions, even on warming, could the faintest odor be detected in the effluent from these filters, while it was always most palatable, the objectionable tastes of the reservoir water having been entirely removed.

The following are particulars of the construction of this filter, quoted from a report made by the writer to the board:

The tank containing the filter is made of 18-gauge corrugated galvanized iron, is 9 ft. 10 in. in diameter and 10 ft. deep, and has an effective area of 75.97 sq. ft. The underdrains consist of a brick arch composed of bricks loosely laid with very wide joints, extending across the middle of the tank to the outlet. This arch is covered with $1\frac{1}{2}$-in. gravel which is $1\frac{1}{2}$ in. deep at the sides of the tank away from the arch and rises in the center to just cover the bricks. Over this is placed 3 in. of $\frac{3}{4}$-in. gravel, then 2 in. of $\frac{1}{4}$-in. gravel, 2 in. of $\frac{1}{8}$-in. gravel, and 2 in. of coarse sand (effective size 4 mm.). The finished layer presents the same sloping appearance as the first gravel layer.

The filtering medium is composed of 3 ft. of sand obtained from the Enoggera Creek, having an effective size of 0.27 mm., 60 per cent. finer than 0.69 mm. and a uniformity coefficient of 2.5.

The water is led on to the filter through an iron pipe and falls

into an iron trough placed 2 in. above the surface of the sand. The trough is 12 in. wide and rests on baffle plates extending 6 in. on each side to effect an even distribution of the water. The exit is through a horizontal pipe level with the bottom of the tank.

The filter was started on the 21st of June, 1906, with a rest interval of four hours in twenty-four; between that date and the 7th of January, 1907, when the method of application was altered, raking to remove surface choking was necessary seven times. The average quantity per acre filtered between rakings was 70 million U. S. gallons and the rate of filtration averaged 2.8 million gallons per acre per day. From the 12th January until the 15th February, water was applied at intervals of one and one-half hours, 6 in. being delivered in three minutes at the commencement of each interval; this caused the filter to choke very rapidly. On the 16th February the interval of rest was increased to eight hours in twenty-four, and on the 19th Feburary the rate was increased to 6 million U. S. gallons per acre per twenty-four hours. The filter required raking on the 25th February and the 12th and 22d March; in July of the same year the records at hand show that the filter had been given no further raking and showed no signs of further choking. The results are shown in Table 5.

TABLE 5.

Average Composition of Effluents from and Percentage Reduction effected by the Intermittent Sand Filter.

	Average of Thirty-Two Determinations during the Period 21st June to 19th February, 1907. Rate of Filtration, 2.8 Million Gal. per Acre per Day.		Average of Six Determinations during the Period 20th February, 1907, to 24th April, 1907. Rate of Filtration, 6.0 Million Gal. per Acre per Day.	
	Parts per Million.	Per Cent. Reduction.	Parts per Million.	Per Cent. Reduction.
Free ammonia	.01	70	.01	61
Albuminoid ammonia	.13	51	.12	49
Oxygen consumed in 15 min.	1.2	28	1.1	24
Oxygen consumed in 4 hr.	2.3	33	2.0	33
Iron (total)	.14	63	.12	62
Dissolved oxygen	7.3	..	7.8	..
Turbidity	nil	..	nil	..
Color (platinum scale)	11.7	55	7.3	63
Odor	nil	..	nil	..

A filter designed and operated in a somewhat similar manner and for a similar water was, I understand, in successful operation for some time at Springfield, Mass., and has been described by C. F. Story in the proceedings of this Association.*

In January, 1907, Mr. Allen Hazen visited Brisbane on behalf of the Brisbane Board of Water Works. In his report, which of course dealt with the whole question of the Brisbane water supply, he recommended, for the treatment of the Enoggera Reservoir water, the construction of a filter working intermittently, similar in design to the Ludlow filter at Springfield. Latest files of the Brisbane papers describe this filter as practically completed.

The work which has been described in this short résumé was performed almost entirely under the supervision of Mr. John Kemp, the board's chief engineer, to whom the writer is indebted for much advice.

The writer would also like to seize this opportunity of expressing his gratitude for the ever-ready and helpful advice given him in correspondence with Mr. Allen Hazen and his partner, Mr. G. C. Whipple, throughout the whole period over which these experiments were carried out.

DISCUSSION.

Mr. Robert S. Weston.† This Brisbane supply is an exaggerated Ludlow reservoir, and evidently required extreme treatment. There is so much organic matter and dissolved iron in the water that it becomes almost a sewage disposal problem rather than one of water purification. The problem has been solved here by giving the water an unusual dose of oxygen. I wondered, in reading over the paper, if Mr. Wasteneys had tried the distribution of the water on a sand filter continuously, by means of sprinklers, instead of using a period of application followed by a period of rest? This method, as all know, has proven most efficient for sewage disposal. One would think it might be worth while trying for the purification of a water containing as much organic matter and iron as does this Brisbane water.

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*Journal N. E. W. W. A., Vol. XXIII, p. 229.

†Sanitary Engineer, Boston, Mass.

I think the Association is very much indebted to Mr. Wasteneys for this very important contribution to our knowledge of the purification of waters which in our tropical country and in the southern states are coming more and more frequently into use. I remember an experience of my own in connection with the water supply of Henderson, N. C., which formed the subject of a paper,* read before this Association, at the meeting in Portsmouth in 1898, where I found huge growths of Bryozoa which obstructed the pipes and grew on the woodwork around the intake, and aggravated any nuisance due to the presence of algæ.

The President. While waters of this type are more common in the South, we do have waters of this general character quite far North, although perhaps not as aggravated as in the South.

Mr. Elbert E. Lochridge.† Taking up one point that Mr. Weston brought up, the question of whether aëration on to a bed with a continuous filter would not accomplish the same result as an intermittent filter, I would like to say that in the experiments which we carried on at Ludlow we found that it was possible to get by aëration on to the beds on continuous filters a fairly good water, but that this was entirely a function of the rate. That is, if the rate was low enough to give a clear, low-colored water, with low organic content, the oxygen was entirely exhausted in the effluent, and accordingly we had that secondary odor which is very much more objectionable than the primary; while if the rate was higher, we could still get a fairly clear water, but not as effective as in the case of the lower rate and the higher resulting odor. While it was found that the water could be purified in that way, it was decided when the time came for the construction of the big plant that the additional oxygen, which could be secured by the intermittent action, was worth while.

On the question of the Ludlow water, I will state some of the later experiences in connection with this system, and a few thoughts on the whole question of growths in reservoirs. Up to the time of the construction of the filter at Ludlow, the water was uniformly bad nearly every year. Since that time it has reformed. I don't know just the cause, but the larger growths, such as weeds, sprouts,

* Journal N. E. W. W. A., Vol. XIII, p. 20.

† Chief Engineer, Springfield Water Department.

and even trees, in the shallow water, have been cleaned up, the reservoir has been raised in the last year or two, and it has been kept somewhat fuller, so that this year there has not been a thing about that water which could be objected to. There is even another town now clamoring for the use of it, specifying that they want it, and the town of Ludlow has been using it without any objection at all through this entire summer. Of course we cannot guarantee it for years to come, but it shows that even with a very hot summer it may be possible in some of these reservoirs, by deepening them or changing the conditions in some way, to avoid the troubles which have heretofore been experienced.

As to filtration and later aëration, there is no question that the aëration which follows the filtration is of a great help in improving the water, particularly in the reduction of what we have always termed the secondary odors, which are entirely distinct from the odors of the organism itself, and which seem to be caused by some by-products in the oxidization of the organic matter.

THE PRESIDENT. As I saw these various processes in use experimentally at Enoggera, there were several of them which, if they had been operated by themselves, effected so great an improvement in the water that any one would have thought the processes remarkably successful, but the process involving intermittent filtration, either as last carried out or with the Morry filter, which was simply an intermittent filtration followed by sand filtration, always produced an effluent which was so much more attractive in appearance and taste and odor than the effluents of the other processes, that, seeing them all there side by side, there was no hesitation in selecting it as the one best adapted to the existing conditions. I think that explanation is a very proper one. The other processes did improve the water tremendously, and if considered by themselves might have been thought very creditable and possibly sufficient. This is a type of water which has been little studied in the past, and I feel that it is a type that we shall have to study a great deal more in the future.

MR. FRANCIS T. KEMBLE. Mr. President, can you tell me with regard to the deterioration of water after being filtered, as compared with the way water keeps in its natural condition?

THE PRESIDENT. I will answer in regard to Brisbane, and what

I say applies in general to other cases, according to circumstances and variations. It is absolutely impossible to store filtered water in the climate of Brisbane in an open reservoir without having it go to pieces and destroy the effect of the filtration. The only way is to have covered reservoirs for filtered water.

This is largely true here also, but there are places in the North where the summer temperatures are low, and where the water is used so rapidly that covered reservoirs are not needed. Mr. Cook has a case over in Paterson where open reservoirs have been used without any serious trouble, at least from organic growths.

Mr. George C. Whipple * (*by letter*). Mr. Wasteneys' paper is a valuable addition to the literature of water filtration experiments. It is all the more valuable to us because the methods of analysis used have been those of the American Public Health Association. It is gratifying to those who spent so much time in preparing these methods to find that they have been of service in other countries as well as in the United States. It is interesting, also, to find that the waters of Australia are troubled with the same pests that are so common in surface water supplies in this country. In this respect, as in many other things, Australia is more closely allied to the United States than it is to Old England.

Most of the studies of algæ have been made thus far in comparatively cold climates where the changes between summer and winter are of considerable magnitude. Here is an instance, however, where the conditions of temperature, light, etc., are more constant and severe throughout the year, and it is not surprising, therefore, that the algæ growths should be greater than those with which we are familiar. It would have been interesting if the author had included in his paper some detailed results of his microscopical examinations.

The author speaks of transforming the color determinations obtained by the Lovibond tintometer to the platinum standard by means of a simple computation. It would be convenient if this method of computation were stated, as it might be useful to others in comparing data obtained by the use of this instrument. In looking over the table of analyses of the Enoggera Reservoir (Table 1) it is noted that the color of the water from January

* Consulting Engineer, New York.

to July was always above 40, but that from August to December the colors ranged from 22 to 32. Inasmuch as this change in color corresponds with the change in the use of the tintometer, the question arises as to whether the former was due to an actual change in the character of the water or to differences in the method of measurement used.

The construction of the Enoggera filter is of interest for another reason, namely, that it is designed solely for the purpose of obtaining a supply of clean water. Here is a case where the water supply is taken from a practically uninhabited watershed and yet filtration is deemed necessary. This is in line with modern progress. American engineers are learning that in spite of the stripping of the soil from reservoir sites, the drainage of swamps, the use of copper sulphate, etc., the algæ problem still remains with us. We are coming to believe that it is better, and in the end cheaper, all things considered, to solve this problem by the filtration of the water rather than to resort to any of the halfway measures, useful though they may be as temporary expedients. In designing water filters for this service the great thing to be always remembered is that plenty of oxygen must be provided. Aëration is destined to play an important part in water purification where the problem of algæ removal is involved.

Mr. Hardolph Wasteneys (*by letter*). With reference to the point raised by Mr. Weston as to application by continuous sprinkling as in sewage treatment I would like to point out that this, in effect, was tried at Enoggera with the slow sand filters, where aërators, as mentioned in the paper, were placed at the inlets to the filters and complete saturation of the applied water was obtained. There was the difference, however, that the sand surface was kept submerged. Our results were similar, under these circumstances, to those mentioned by Mr. Lochridge as having been obtained at Ludlow. We did not, however, try continuous sprinkling on to the exposed sand surface.

In reply to Mr. Whipple's remarks I regret that I have not at hand any records of biological analyses of the Enoggera water made during the period under review. As regards the method of computation employed to convert the units of the Lovibond tintometer to parts per million on the platinum scale: The method

used was to multiply the number of units of yellow on the Lovibond scale by 9. This gives a figure which approximates very closely to observed values on the platinum scale as indicated by a large number of parallel observations, though when the colors are very high, i. e., over 60 on the platinum scale, the comparison is less accurate. The high color observed for the month of May, 1906, is due to the annual overturning of the reservoir contents which takes place usually during that month. I must confess that the sudden drop in the color figures during the period August to December, coincident with the use of another method of determination, looks significant. It was, however, undoubtedly due to the change in color of the water, as, even after the institution of platinum cobalt standards, the use of the Lovibond standards was continued and the figures show a corresponding decrease in yellow units.

During the months May, 1904, to January, 1905, estimations of color were made in the standard color tubes with glasses graded to indicate parts per million of platinum according to the United States Geological Survey method. The following figures then obtained may be interesting to compare with the figures quoted in my paper for the same months of 1906. It will be seen that they are (with the exceptions of May and January) almost identical.

MONTHLY AVERAGES OF WEEKLY DETERMINATIONS OF COLOR.

Month.	Color, Platinum Scale.
1904.	
May	50
June	52
July	41
August	37
September	32
October	32
November	21
December	21
1905.	
January	20

HAS THE TIME COME FOR DOUBLE MUNICIPAL WATER SUPPLIES, ONE — NATURALLY PURE — FOR DRINKING AND COOKING, THE OTHER — DENATURIZED OR STERILIZED — FOR ALL OTHER PURPOSES?

BY W. T. SEDGWICK AND H. P. LETTON.

(From the Sanitary Research Laboratories of the Department of Biology and Public Health, Massachusetts Institute of Technology, Boston.)

[*Read November 8, 1911.*]

It has often been proposed that two water supplies be provided for cities, one to furnish water of the highest quality for drinking and cooking, and another for all other purposes. The advantages of this plan were recognized as far back as the time of the Romans. Frontinus,[1] writing in A.D. 97 concerning the water supply of the city of Rome, states that the water from one aqueduct was used exclusively for drinking and cooking purposes, that from another aqueduct for baths, and that from others only for irrigation. In modern times the question has also been seriously considered, Brackett [2] having made a report to the Metropolitan Water Board in 1895 on a separate supply for the city of Boston. The subject has also been discussed in a more general way by Axtell,[3] McElroy,[4] and others.

Our large cities with but few exceptions obtain their water supply from rivers, lakes, or large artificial storage reservoirs. These sources are in some cases grossly polluted, and many that are not polluted at present are in constant danger of becoming so, notwithstanding the fact that elaborate precautions are taken to guard against contamination. In case the present supply is polluted, the city will generally be compelled, sooner or later, to go to the expense of constructing a filtration system or of obtaining a new supply from a more distant, non-polluted source. Cities having as a source of supply lakes or artificial reservoirs must maintain a constant and efficient oversight of the watershed in order to guard against pollution. Moreover, no matter how complete and efficient the system of filtration or the supervision of the

watershed, these provisions are not always infallible as safeguards. This is shown by the typhoid fever epidemics at Lawrence, Mass., and elsewhere, due to trouble with the filters, and those at New Haven, Conn.; Scranton, Pa.; Plymouth, Pa.; and many other places, due to pollution of the watersheds feeding the storage reservoirs.

We are at present in a peculiar position — namely, when most of the water supplied to our modern communities is not used either for drinking or for cooking, and yet, since any of it may at any time be used for these purposes, all of the huge streams that pour through our cities are expected to be, from the sanitary standpoint, above suspicion. Thus far we have got on fairly well under this arrangement, but the time will probably come when the amounts so required will become so vast, and so costly to keep up to the required purity, that we shall be driven to double supplies, one for drinking and cooking, the other for all other purposes.

Even if it be granted, however, that with proper precautions the danger to the public health from ordinary water supplies is small, the question still deserves to be considered whether from a sentimental or esthetic standpoint the time has not come for double municipal supplies.

For it is an open secret that many persons dwelling in cities provided with filtered water supplies derived from polluted sources cheerfully purchase spring or other waters which they believe to be naturally pure rather than drink the purified waters which are known to come from sewage-laden sources. It must be admitted, moreover, that it is by no means agreeable to dwell in detail upon the proximate sources of some of our most reputable water supplies, derived as these often are more or less directly from streams laden with human excrements or with street washings, the drainage of slaughter houses, of hospitals, and the like. Some years ago we were grateful for even a moderate degree of cleanness, but our standards in these matters are constantly rising, and decency is everywhere more and more being added to health as a consideration of importance in public affairs. Again, many filtered waters are at times colored or turbid, or have a disagreeable taste or odor, due to the presence of organic matter not removed by the filters, although the bacterial efficiency of the latter may be high. Water

obtained from impounding reservoirs is also often colored, and of a marked taste or odor, due to the growth of microscopic organisms. The New York and the Boston supplies are examples of this type. In order to prevent such growths the reservoir is sometimes during construction, at great expense, completely stripped of the top layer of soil; and even then the result may be only partially successful. Again, a water from a surface supply is frequently quite warm during the summer months and correspondingly less potable than a ground water with a fairly constant temperature all the year round.

The average daily per capita consumption of water in cities of the United States, with a population of 100 000 or more, is about 115 gallons, and of this amount Brackett [5] has shown that not over 35 gallons are used for domestic purposes, while the amount actually used for drinking and culinary purposes is less than 3 gallons. If, however, we allow 10 gallons per capita per day and consider the fact that this would only be 1 000 000 gallons per day for a city of 100 000 population, we see at once that it would be possible in practically every case to obtain a sufficient supply of ground water that would be purer and more potable than most surface waters, even if these last are filtered.

We are in the midst of a mighty sanitary awakening, and are spending millions of dollars every year in protecting and purifying our water supplies, yet of all the water distributed probably less than three per cent. actually concerns the public health. With this fact in mind it is evident that we seem to be following an uneconomical course, and that any plan for betterment should be thoroughly investigated.

Heretofore, whenever the question of a double supply has been proposed, the one insurmountable objection has been that it would be impossible to prevent people from drinking from the second and impure supply. This was clearly shown at Lawrence, Mass., in 1893. The city used a filtered supply from the Merrimac River, while in some of the mills the raw river water which was badly polluted with sewage was used for washing. During the year there were nine deaths from typhoid fever of mill operatives who had drunk the river water notwithstanding the fact that they had been

fully warned of the danger, while the total number of deaths from typhoid in the entire city was only seventeen.

In order to make the double system practicable it is necessary (1) *to so regulate the use of the smaller supply that it shall not be wasted*, and (2) *to so treat the larger supply that it shall not under any circumstances be used for drinking.*

The first condition could be attained by making the cost of the water such that its value would be appreciated, and by metering all services. It is the second condition, or that of *denaturizing* or *sterilizing* the supply, so to speak, that is the main object of consideration in the present paper.

In recent years there has come into general use an agent which it is believed will be a satisfactory *denaturizer*, both from a sanitary and an economic standpoint. This substance is calcium hypochlorite [Ca $(OCl)_2$], which is being extensively employed as a sterilizer for water and sewage. Its especial fitness for the case under discussion lies in the fact that if put into a water in such quantity that it is not all decomposed, it imparts to the water an odor and a taste that are very disagreeable. With a water thus treated its use for drinking would be very rare, and even if it were so used no harmful results would follow, as the water would be practically sterile and as a little undecomposed hypochlorite is probably not detrimental to health. Brackett has shown[5] that about ninety per cent. of the water used for domestic purposes is employed in flushing water-closets, in wash tubs, in bath tubs, and in sinks and bowls. The addition of the hypochlorite would not affect the use of the water for any of the above purposes if we except the small amount used for drinking and cooking. From the same authority it appears that of the water used for commercial purposes the larger portion is employed in steam railroads, factories, elevators, power plants, and office buildings. The hypochlorite would affect the use of the water in very few, if any, of the above cases. It is also quite evident that it would not affect the public use of the water for such purposes as street sprinkling, ornamental fountains, sewer flushing, and fires, but would instead be a benefit on account of its disinfecting action.

From a consideration of all the above facts, it appears that as a sanitary measure the plan is highly commendable. To determine

whether it is economically practicable is a much harder problem, as this will be established largely by local conditions. It would, of course, be necessary to install a separate distribution system, and, although this would be of much smaller piping than the present one, it would still be the large item of expense. Separate services and meters would also be required, which would be another large item. These, however, are points which would have to be considered as special problems in each individual case.

The object of this paper is merely to present the plan as it stands to-day to water-works officials, engineers, and sanitarians, in the belief that it is a new aspect of an old problem, and one that can be, and will be, profitably applied in some cases in the near future.

REFERENCES.

[1] Herschel. Frontinus and the Water Supply of the City of Rome, p. 65.

[2] Brackett. Water Supply of Different Qualities for Different Purposes. Report Massachusetts State Board of Health on Metropolitan Water Supply, 1895, p. 217.

[3] Axtell. Pure Water for Drinking and Cooking. *Eng. Mag.*, 1896, xi, p. 67.

[4] McElroy. City Water Supplies of the Future. *Eng. Mag.*, 1894, vi, p. 821.

[5] Brackett. Consumption and Waste of Water. Am. Soc. C. E., 1895, xxxiv, p. 185.

DISCUSSION.

Mr. Charles W. Sherman. The paper certainly presents a very interesting possibility, and there can be no question from an engineering point of view that it would be practicable. The only question, as it occurs to me, is the economic one, which the authors have already called attention to. It would unquestionably mean an expensive water supply to furnish a double supply in this way. It is perfectly conceivable that there may be cases where that expense would be warranted.

The President. Will Mr. Weston say something as to the probable effect of an excess of chlorine on the pipes and other water-works fixtures?

Mr. Robert S. Weston. Mr. President, I was just about to ask the author of the paper that question. I wondered if that would not be an objection. I should think the addition of chlorine would make the water more corrosive than it was before; whether it would be appreciably more so or not, I could not say.

Mr. Arthur N. French. You may be interested to know that

we are using chloride of lime (about six pounds per million gallons) at Hyde Park. I do not know that there is any other place in Massachusetts that is doing it. We have been using it for about a year, and I cannot see that there is any effect upon the water that is disagreeable. People drink it and do not make any objection to it. Our water is well water, and it is fairly clear and does not carry very much sediment. We began to use it because we had a typhoid-fever scare last year, there were several deaths, and we started the use of it as a matter of safety. The State Board of Health have knowledge of it, and have been out to investigate it, but they have neither approved nor disapproved. I cannot see that it corrodes the pipes any more than the plain water did. It corrodes the implements that we use in mixing up the solution very badly. Wooden pails will last only a very short time, and galvanized iron is eaten out fairly quick. Our plant is only a temporary one, for we expect to take the Metropolitan water now in a short time, so that we have not put in anything permanent.

The President. If you will try using sixteen pounds for a day or two instead of six, you may get some new light on the smell question.

Mr. French. Of course that would make a difference.

Prof. E. B. Phelps. Mr. Sherman's remarks as to the expensiveness of this plan seem to me not to be of general application. One can easily conceive a situation in which a town is face to face with the proposition of going quite a distance and at considerable expense for a new supply of sufficient magnitude and proper quality for all purposes. Now if there be near at hand a supply of ample magnitude, although of inferior quality, it might not be necessary to go so far afield for the small pure supply, and it seems to me in such a case this plan might easily work out a real economy.

In regard to the question of corrosive action, I can state that I have had under my personal observation three installations in which water is pumped which has been previously treated with hypochlorite. I have had special notice taken of the interiors of the pumps from time to time and there has been thus far not the slightest sign of any injurious action. One of these plants has been in operation for about ten months and the water is receiving

hypochlorite in the proportion of about $7\frac{1}{2}$ lb. per million gallons, and the others have been in operation for eleven months and two years respectively, the hypochlorite averaging about 8 lb. and running as high as 12 on occasions. Furthermore, in none of these cases, nor of several others which I have had under my immediate observation for some time, have there been any unusual complaints from or indications of corrosion in the pipes. A careful study of the chemical principles involved has led me to believe that the action of this extremely dilute and slightly alkaline solution is protective rather than otherwise, a conclusion which I think is amply justified in the results. In a concentrated form in which the solution itself is handled it is quite true that the slight protection due to the alkalinity is more than offset by the corrosive properties of the free hypochlorous acid liberated.

Mr. Randolph Bainbridge. I might say that in the city of Quincy at the present time the Fore River Shipbuilding Company uses about half a million gallons of water a day, and having found it expensive to buy Metropolitan water, has a double supply with a reservoir of its own. All fixtures connected therewith are labeled "Industrial Water." As far as I can find out from observation, from what my men tell me, and from what the men at the plant say, there is absolutely no trouble whatever with anybody using the wrong water.

In this connection I might say that this water is not treated in any way whatever. It is simply that the water from the reservoir, which is, as has been described, street water, and water from fields and barnyards, and so on, is used solely for industrial purposes, the Metropolitan supply is considered good enough for anybody to drink. Last winter the company wanted to enlarge the plant to about a million gallons a day, and use the old Quincy reservoir, and in fact entered into a contract with the city to do so. We found, after we had made a contract, that the state would want the city to pay them three times what we could get from the company. In other words, we have a reservoir that is good for a million or a million and a half a day, and which would answer the very purpose we have been speaking of, a secondary supply, but we have to pay the state for the privilege of using it about twice what we can get for the water.

But there is no question whatever but what this thing is coming. The farmer, the granite man, and the manufacturer at the present time do not get a square show at the water. What you have to charge in any water-works system, whether 20 cents or 15 cents or 10 cents a thousand gallons, is practically robbing the manufacturer, and I do not suppose that this shows up in any other city plainer than it does in Quincy. Lots of our people use well water for boilers, but that makes work for the boiler men. As has been said, about 5 gal. a day of pure water is enough for practically all that a secondary supply would be needed for, and large local supplies would thus be available for industrial purposes.

Mr. Frank C. Kimball. That the time is coming when some conservation of potable water will have to be made, I think is beyond question. Whether a double supply can be put in at an expense which will pay from the present standpoint of proper charges for water is a question. If, as Mr. Bainbridge has suggested, a charge of ten cents a thousand gallons is too high for water for such uses as he mentions I doubt if the time will come very soon when even industrial water can be treated in such manner that it cannot be used for domestic purposes, and at the same time not so radically treated that it will not be offensive for other purposes, at much less price than that, separate distribution and pumping also being considered. I am speaking now, of course, of municipal supplies as a whole. This is a subject, however, that I think it is very pertinent for an association like this to consider, and sooner or later the problem of a double supply of water will have to be worked out for some communities, although it will probably be a long time before it is necessary for the majority of them to take up this question.

Mr. John H. Cook. Mr. President, this matter is, like the tariff, a local question. There may be times when it will pay, and there will be other times when it will not pay. It seems to me every situation would have to be judged by itself. So far as treating the water successfully without making it offensive goes, I think that it generally can be done without trouble. We have treated some 40 million gallons a day for the people of Jersey City, as is doubtless well known to many gentlemen here, for some time, and without any complaints whatever from the people who have used

the water. The treatment is extremely inexpensive, and I should suppose that with most waters it would be perfectly satisfactory, except to a man who knew it and did not like the idea of it. My idea is that it will be a long time before a double supply is generally introduced in our communities. We have a great many mills that are supplied, or were supplied formerly, with two separate systems, one system for toilet purposes and another for drinking, but that was never a very successful proposition. The employees insisted on drinking the wrong water, although the taps were all labeled with brass tags which said, "Do not drink this water," or, "This water for drinking purposes." The help would drink indifferently and we did not find it at all successful.

Mr. Sherman. Mr. Phelps's question suggests that possibly I might amplify my previous remarks a little, with regard to the expense of the proposition, and bring out more clearly the point which I especially had in mind. I do not doubt that the distribution system and the supply works could be put in in many cases at a cost which might be feasible; but when it came to a duplication of the plumbing, I think the householder would feel it very seriously, unless it was in the comparatively rare case where he is willing to pay twenty dollars or thirty dollars a year for spring water in addition to the ordinary house supply. In cases like that he might be willing to stand the double plumbing expense.

The President. I think the double plumbing is a very important question. I would like to know what the plumbing in a city costs as compared with the water supply. It is my impression that in Boston the plumbing costs more than the Metropolitan Water Works. Does anybody know about that?

Mr. George A. Caldwell. The cost of the plumbing for a separate supply for drinking purposes only would not be a serious matter. For an ordinary twelve-room house with, say, four outlets for drinking water only, the cost of the extra piping, using brass pipe, not including the meter or the service from the main to the house, would not exceed $50, including all labor and material for the work. In many cases the cost would not exceed $25, and I believe the average cost based on a twelve-room house with four outlets would be about $35.

Mr. John C. Chase. It strikes me that the installing of two separate sources of supply in an ordinary community would be a very serious proposition to consider. I can see only one way in which it would be practicable, and that is that the residence portion should be supplied with pure water, and the business and manufacturing sections with the second quality for commercial purposes so arranged that none of it could be used for drinking purposes. Moreover, the ordinary dwelling house would not use such a great amount that it would be necessary to supply it with a secondary supply; and in the manufacturing sections, I think it would not be a very difficult matter to arrange for the use of a water that is not up to the required standard for domestic uses, segregating it to such an extent that there would be no danger of using it for drinking purposes.

I have in mind a case in Haverhill, Mass., where typhoid fever appeared in one of the factories a few years ago, and, if I remember right, it was found that the help instead of using the city water were drinking from a nearby faucet which was supplied with impure river water. I think it would be utterly impracticable to put two kinds of water into a place where there is a chance of the undesirable one being used. My experience with the average workman is that he will take what is handiest.

The President. I remember that this system was used some years ago, though perhaps not fully, at Augusta, Me., when the main supply at that time was taken from the Kennebec River, and a spring-water supply was piped throughout the city and into nearly all residences, and was sold separately. This was known as the "Devine Spring Water." I was much interested in that when I first heard of it, but I found that the name came simply from a Frenchman on whose farm the spring was located. Afterward Augusta secured a new supply of excellent quality and the Devine spring fell into disrepute.

Professor Sedgwick. *Mr. President and friends,* — I want to begin by saying how glad I am to be here again and to see the faces of so many old friends, and of those who would, I am sure, be new friends if I were fortunate enough to be able to attend more of your meetings. It has been a real regret to me that for the last few years I have been able to be present so seldom. But I am sure

since I see so many of the old officers are still on deck, and so many of the old members still present, that the Association lives up to its old traditions. And it was with that feeling that Mr. Letton and I brought this paper here to-day.

In a discussion before one of our classes, last year, concerning the use of calcium hypochlorite for the treatment of water, a use to which this material is already being put for one purpose and another, Mr. Letton used the happy term *denaturizing* the water; whereupon I asked him to work up this subject of a double supply and bring it up to date. I remembered Mr. Brackett's old paper, and I have long been impressed, as, of course, everybody has, with the fact that while most of the water that we have in our cities is not used for drinking or cooking, all of it has to be fit to drink or for cooking, — a condition which is certainly anomalous, and which in certain cases and under certain conditions leads us to inquire whether we cannot do something about it.

There is another side of the subject which appeals to me very much as a sanitarian, and has long done so, and that is this: What I call the sentimental objection to a water which is hardly more than filtered dilute sewage. Now, I would not for a moment go back on filtration; let that be distinctly understood. The introduction of filtration has been one of the greatest blessings that ever befell the community or the water-works profession. At the same time, there is no doubt that it is not a pleasant thing to sit down and reflect, if one must do so, that the particular drinking water which comes to his table, or into his kitchen, and is used for cooking and drinking, is separated from dilute sewage, in which you can see fecal matters, by a little layer of sand only a few feet thick. The origin of drinking water is important, and that is recognized by all filtration men. The purer the raw water, the higher the grade of it, the better. There are communities, and I could name some of them, where the water supply is hardly more, from one point of view and stating it in its worst way, than filtered dilute sewage. And it is a great comfort to be able to know that we can filter a highly sewage-polluted stream in such a way as to make it powerless to injure the public health. At the same time, it is not always a pleasant thing to stop and think of what went into the water just before it was filtered, or what was in

it at the time. There are communities that would gladly pay a good deal if they could get a pure upland water rather than have filtered water derived from a source of the sort to which they must now go.

With those thoughts in mind, and recognizing, as I must as a sanitarian, the fact that our standards are constantly rising, and that decency is everywhere to-day being linked up with hygiene and sanitation, original cleanliness getting an increased value all the time, it seemed to me worth while for Mr. Letton to work out this matter, and I took up the subject afterwards with him with a good deal of interest.

Now, to begin with, when we have two kinds of public water supply, one of which is good and one of which is bad, there is absolutely no insurance against the use of the bad supply by careless people. That idea has been emphasized sufficiently already, and it is a well-known fact that there are plenty of people in a community who, if a water looks fairly well and tastes fairly well, will drink it even if there is a sign right over the tap from which they draw it saying that the water is not fit to drink I remember seeing that illustrated in Lowell and in Lawrence, and I remember seeing it in Italy, where they had the same sign (*aqua non potabile*) over some of their waters that are not supposed to be used for drinking. Of course you may say that that is of no consequence except to the man who disobeys the rule; but it is of great consequence to the community, because every case of typhoid fever or other infectious disease arising in a community, even in a person of no particular consequence *per se*, is of great importance, or may be of great importance, to the community. Every such case is a nest or a focus of disease from which disease may spread. If, for example, it is a careless workman who comes down himself with typhoid fever, you may say, "Well, he is simply paying the penalty for his carelessness." But if that man has typhoid fever in his home, and his sister, or his sister's daughter, or his own daughter, happens to be a servant in your kitchen or mine, or in your nursery, and brings the germs of the disease to your house or to mine, it then becomes a matter of serious importance to the whole community. "We are all members one of another" nowadays even more than in ancient days, and getting more and more so as

population thickens. So that, even in the case supposed, it is not merely the penalty the man pays who drinks the wrong water; it may be the penalty which the community pays for having the bad water accessible for drinking.

This has been and always will be the objection to two supplies, one good and one bad and infected with the germs of disease. But this plan of denaturizing the water removes that objection. The proposition is simply to treat the inferior water in such a way that if it should be used for drinking, for which it is not expected to be used, no harm will result, unless it be a bad taste in the mouth, possibly, if the denaturization is strong enough for that. At any rate, the water by the denaturizing agent used will itself be made practically sterile. And in that connection I may say that it is not necessary to so overload the water with the hypochlorite that it shall have a bad odor or taste, although on some accounts it would be well to do that. It is sufficient if enough be added to sterilize the water, and that can be done judiciously, as has been shown in many communities, without producing a bad taste or smell. It is not, then, a question between a bad smelling and bad tasting water and a good water; it is a question between two kinds of safe water, one derived from sources naturally pure and above objection on the score of sewage origin; the other, not standing in that category, but coming from objectionable sources.

The whole object of the paper, however, is merely to emphasize the fact that we now have in our possession a material by which we can, if we want to, denaturize any water, and more than once this method has been used in emergencies. When, for example, a typhoid fever epidemic has broken out, as in Torrington, Conn., lately, and it was necessary to do something immediately to the water, a quick disinfecting plant with this same hypochlorite was introduced, as has been done in several similar instances, and the water going to everybody has been denaturized for a time. In the state of Kansas I noticed the other day, in the report of the State Board of Health, they keep, so to speak, a " wrecking train " ready; that is to say, they keep an emergency hypochlorite plant on wheels ready to run off to any town in the state that has a typhoid-fever epidemic due to the pollution of its water supply. That would be a good plan in any state where the water supplies are

seriously open to suspicion. It is, in fact, done in more places, I fancy, than is commonly reported. The wise State Board of Health will everywhere have in its engineering department, if it suspects the likelihood of any such need, some such plant always ready for energencies. This, as I have said, was the main point, to bring the matter up here for discussion.

On the economical side, we realize, of course, that cities that are already provided with good water supplies would never think of embarking on this scheme; neither would those cities which can get abundant water think of doing anything of the kind. It will only be in some special, peculiar situations, where water from a good source cannot be obtained in sufficient quantity, except at an almost prohibitive expense, or where for some local or peculiar reasons it may be desirable to have two systems of supply. But it seemed to me, and I think the discussion has justified the belief, that an Association like this, that is always anxious to know whatever good is going on, and whatever is possible under new or trying conditions, might take this up and discuss it with advantage; and I am sure that both Mr. Letton and I are well satisfied with the discussion that has taken place. It has brought out exactly the objections which might have been anticipated, and a rather surprising amount of concurrence with our general contention, which is simply this: That we have here a new agent, useful under certain circumstances, the whole thing being, as Mr. Letton said, simply a new aspect of an old problem.

SOME NOTES ON TROPICAL WATER SUPPLY AND A STUDY OF FILTRATION AT PANAMA.

BY HERMAN K. HIGGINS.

[*Read November 8, 1911.*]

One may find in the history of a frontier community a condensed compendium of the history of the race, the swiftness of which is perhaps well exemplified by the moving pictures we sometimes see, showing us, in a fraction of the time really consumed, such a scene as a vessel traveling in a lock, bobbing back and forth with no apparent reason, the men on the bank running and jumping with expressions of entire leisure. The view so presented is likely to seem in the retrospect more amusing than historical.

The history of Panama water supply, of which general subject filtration is one of the lesser phases, certainly seems from this distance amusing enough, but was, in the enacting, fraught with trials and tribulations. A short historical sketch from the standpoint of an interested spectator and innocent participant may serve to introduce the subject.

> It was in the gray November,
> Well the morn do I remember ;
> Dark and angry clouds hung lowering,
> And the tropic rain came pouring,
> As it oft had poured before,

might from several standpoints be considered a fit setting for the picture. Mackintosh and umbrella were checked a mile away.

The writer sought for a cooling drink; he did not like to patronize a saloon, but he finally found that it was the only place in which anything to drink could be had for love or money. The fluid served was bad, but not so bad as nothing.

Tropical Colon and Panama had for many years provided for themselves and visitors a limited supply of alleged-to-be-potable water, more often an infusion of wrigglers and nameless impurities. This water in a state of comparative purity was deposited by the

Tank Car on Panama Railroad, 1906.

too willing skies on the spreading roofs, where, like the unclean spirit in holy writ, it immediately proceeded to take to itself seven — rather seventy and seven — forms of available dirt deposited on said roofs largely from the claws, beaks, and plumage of numerous scavenging buzzards, and at rarer intervals by dust-laden winds. The roofs are mostly steep, whereby the descending flood readily bore its burden to cisterns, or, oftener, to a battery of barrels usually open to further contamination. Some of the more wealthy and intelligent of the natives ran the stored water through a porous earthen filter which removed much of the dirt and, incidentally, or *vice versa*, cooled the water several degrees. Fortunate was the man who had his cistern deep and his barrels well filled. During the dry season his less provident neighbors often retired with a thirst such as Kipling could only find " East of Suez." He never experienced " East of Colon " or he would have said that.

Panama City is said to have had a limited number of wells, of which perhaps the less said the better; they had been filled up, for the most part at least, before the writer visited the city.

Colon, built on a coral reef, had plenty of ground water, but it was too thick to be potable. Unlike the Missouri and Mississippi water, which one to the manor born stirs and drinks quickly, the Colon ground water is so very rich that no amount of stirring would render it drinkable; it might more easily have been rendered eatable.

Thus it was that Colon must depend on rain entirely. Fortunately, the rainfall at Colon covers the dry season fairly well, and only occasionally was there a lack of stored water.

With the development of the Panama Railroad, water supply conditions improved. Water was required at Colon for boilers, hotels, ships, and the like, so a small reservoir was constructed, pumps were installed, pipes laid, and the march of improvement started in earnest. Any deficiencies in storage or rainfall were corrected by the use of tank cars, of which the Panama Railroad had a large number, bringing water from inland rivers such as the Frijoles (Beans) River, which the writer was told never failed, delivering it to the suction main of the railroad company's pumping station (Plate I). The discharge line of these pumps was connected to a high tank in the railway yard, also to the houses occu-

pied by railway officials, consuls, the hospitals, and a few other favored premises, including, by no means least in importance, two water stations some half mile apart (Plate III, Fig. 1), at which daily a long line of the unwashed could be seen with receptacles of all sorts awaiting each his or her turn to enter and for a certain fee draw his day's supply. How much of the fee finally reached the railroad company, deponent could not satisfy himself; the police agent collectors were under very little check.

This phase of the supply lasted till the French Canal Company built the breakwater and on it founded the town of Cristobal. The railway company's supply was limited and the canal company needed water. Judging by published accounts, it was not applied solely to floating equipment or live stock.

The earlier water supply equipment seems to have been quite limited in capacity and extent, the French town was small, water from across the bay was supplied to the De Lesseps houses, to the shops and wharves, and to a centrally located fountain, now no longer extant, from which monsieur drew his daily ration, as did the writer at a later date.

The supply from which monsieur's water was derived was five miles away across Limon Bay. Never-failing springs filled a reservoir from which tank vessels were supplied. These in turn formed the suction wells from which local pumps delivered the water to the town fountain, shops, etc.

At about the beginning of the American régime, a small dam was built across a section of the diversion channel, pumps and pipe line installed, iron tanks were set upon a convenient hill, water was piped well over the town of Cristobal, and soon after practically all the houses were supplied from this local system. The works were, for their capacity, well designed, well built, and, barring certain administrative difficulties, the system gave a very good account of itself. It was of course not always working, as the pipes were laid in loose fill and breaks were frequent. The attendants were negroes who considered the whole thing witchcraft and the plant under the personal control of the devil. It naturally followed that any trouble in the night watches, a leaking plunger, rattling valve, or any unusual sound or sight, put the attendant in a panic. If he was brave, he banked the fires before he ran.

This was true of most of the night firemen. Fortunately the French régime left a large warehouse full of boilers, scores of them. Very few exploded, but the bagged fireboxes were a sight. The practical man in charge of the water system was very short, very fat, very profane, perhaps largely in consequence of his occupation. He was quartered in the room directly under the writer's. His first knowledge of water trouble was usually from some early riser above who wanted a shower, in vain.

A large fraction of the supply was used for boiler feed for both land and floating equipment. The filling of tanks began early and by 6 A.M. the pressure was usually too low to fill the second floor showers. Water could be drawn from faucets lower down for a half hour more. Those who rose later must needs go downstairs and perhaps across the street for any water at all.

Much of this loss of pressure was due to the laziness of the blacks, who never dreamed of shutting a valve. "Throw the hose overboard and forget it" was their rule; *they* needed no water. So it ran to waste all day perhaps, or until some white man saw it.

The boilers generally shut down at 6 P.M. and by 10 P.M. there was usually water all over the town.

This supply was soft, fairly clear, excellent for the toilet, but as it was surface water from a drainage area inhabited for the most part by people whose ideas of sanitation were not far advanced, it was not at all safe for drinking. A galvanized-iron tank screened from mosquitoes, located at a corner of each house and supplied from the roof, furnished a drinking supply for the greater part of the year. These were analogous to the barrels already mentioned in the old town, and, like them, were the occasion of solicitous regard on the part of the sanitary inspectors lest mosquitoes multiply, and therefrom yellow fever. All water barrels and tanks had screens permanently fastened on. They were usually elevated on blocking or low stands, spigots were provided and the natives strictly forbidden to meddle in any way with the screens, on pain of having the barrels summarily destroyed. The penalty for meddling by canal employees was even more drastic. To guard against the annual dry season, this potable supply was reinforced by some half dozen large tanks eight or ten feet in diameter and

fifteen or so high, replenished from near-by roofs and delivering through the ancient French fountain already mentioned.

The wisdom of so reinforcing the weather was abundantly demonstrated during the drought of 1906. The writer has as a souvenir an order for water covering this period. The dry weather was in its way a godsend, giving opportunity for much needed pipe and drain laying, building of streets, and the like.

This temporary supply, both surface and rain storage, was, in the summer of 1906, succeeded by a more permanent arrangement. The authorities of the canal work had early foreseen the need of abundant water for Colon and Cristobal. Surveys and plans had been made, a reservoir site selected, well selected at that, pipe lines laid out, and construction was well in hand when the writer arrived on the scene. The construction forces were located in a most charming camp on the edge of a hill forming part of the proposed main dam. A narrow gage railway had been laid, diminutive locomotives, when not off the track, brought in supplies, cement, tools, and the like, not to mention our strenuous President Roosevelt on his precedent-breaking trip to the canal. A twenty-inch pipe line was being built under great difficulties, from near the proposed gatehouse toward the town. Of this pipe line material a surprisingly large fraction had suffered in transportation or earlier; the line was littered with short ends cut from the cracked cast-iron pipes (Plate II). In the meantime, pipes were being laid in the town, hydrants set, and preparations made to distribute the water. Pending the arrival of the main pumps, temporary pumping stations were established, located at diverging points in the pipe lines, and designed as boosters to take the water from the gravity main, at a pressure sometimes less than atmospheric, and deliver it back into the main beyond the pumps at a pressure sufficient to serve two- and three-story buildings.

It was anticipated that there would be delay in the delivery of pumps and standpipe, and in the construction of the main dam. A small temporary dam was accordingly built across an arm of the proposed reservoir, and an 8-in. spiral riveted pipe nearly a mile long was laid on the surface of the ground connecting from it to the permanent 20-in. pipe below the main dam. This was ready for service early in 1906. About that time the earlier reservoir in the

DEFECTIVE ENDS OF PIPE ON COLON LINE.

diversion channel ran dry, and a connection near it was made to the pumps, and the reservoir water was delivered to the town through the original pipes laid at about the beginning of the United States administration. This water was of excellent quality and we thought our troubles were over, but, alas, the dam leaked, the formation was like a sieve; a few weeks saw the end of that supply. The situation looked so desperate that an order was issued to abandon all upstairs baths and toilet appliances. This order, dated April 1, was to be effective April 4. Late in March, some one discovered that a few feet from the pumps was a branch of the old diversion channel ten or more feet deep, full of water, connected at the other end, a mile or so away, with several full rivers, and at a greater distance with Limon bay and the ocean. A couple of lengths of pipe did the trick. Several days before the above-mentioned order to close toilets became effective, we were startled by the appearance, early in the evening, of fireworks from the phosphorescent salt water in our dark shower baths. Although the occasion for closing was thus averted, the order was nevertheless enforced and for a month we were denied the use of our toilet facilities in second stories, notwithstanding the fact that the pressure was ample, far better than at any time for six months preceding or following.

An amusing incident shows how little the situation was understood at Washington. The *Post* of that city published an article describing the water famine at Colon. The administration gravely explained that there was no water famine, there were $2\frac{1}{2}$ million gallons of water held as reserve in the temporary reservoir. The writer happened to visit the reservoir at just this time and saw the $2\frac{1}{2}$ million gallons — the surface was some three feet below the intake to the pipe line.

The salt or brackish water, excellent for sanitation, was, of course, unsuitable for boilers, consequently the old French reservoir across the bay was put in commission, barges were filled and towed across to serve the dredge fleet, shops, etc.

The native town was still unsupplied with drinking water. After a few days of rioting, not reported in the press, the railway came to the rescue, put its up-country pumps and tank cars in commission, and Colon began to drink again.

About this time Washington began to ask about the progress on the cold storage plant. Assurances were given that the refrigerator cars which had already been delivered were running regularly on the railway. So they were; they made excellent water cars. They were so tight that a very little bulkheading made the most efficient of tanks. The ice for these cars was ready about a year later.

Washington also took a fall out of the salt water supply, the details of which would require too much space to recount here. Quibbles and explanations, very ingenious, were the order of the day.

So it went till early in May the rains began, the runoff caught up with the leaks in the temporary reservoir, the salt water supply was replaced with fresh, and the pressure in the upper stories resumed its high night and low day schedule and we were allowed to resume the use of our toilet rooms.

During most of this time the Panama city supply was better than ever before. (It was the first dry season of the improved new supply.) Toward the middle of April, however, the supply was drawn below the gate chamber inlets. A most ingenious raft was built with pontoons of 16-in. sheet-iron dredge pipe, a pump was mounted thereon, steam supplied from a boiler on shore, and the water was pumped into the gate chamber. The writer saw the raft under construction; the water was warm, the negroes were just short of naked, so the hardship was rather on the consumers than on the workmen. The Panama end has, however, a story of its own.

To return to the Colon and Cristobal story. The new 20-in. pipe line was now nearly enough complete to be used, mains were laid in many of the streets, local pumps in several places were taking water from the 20-in. main and supplying sections of old mains; the distribution system was not in use, gates were closed, there were no hydrant wrenches, nor house connections.

Inventory day was approaching, and on June 6 a fire broke out in the oil house of the commissary store. After some forty minutes hose was brought from the main warehouse a mile away, pipe wrenches were secured and several hydrant streams were playing on the ruins. The fire had one good result, — the hydrants and

distribution systems were kept under pressure and the pumps at the diverging points above mentioned were kept going. Some weeks later house connections were made and local trouble from limited quantity of water was at an end. In due course of time the main reservoir was put in commission, bettering the pressure, as it cut out the mile of 8-in. supply pipe. Still later pumps were installed, supplied by steam through several hundred feet of pipe carefully insulated, being buried in a bed of concrete in a deep trench.

This steam pipe line was put in to avoid tramming the coal the several hundred feet to site of pumps. Later oil fuel was substituted, and still later the boilers were moved to the pump station, after tests had shown a remarkable steam comsumption for this station. Published tests showed 53 lb. per indicated horse-power. These permanent pumps allowed the elimination of the local pumps scattered over the town, and further improved the pressure. On the completion of the standpipe on a nearby hill, the system was complete.

But the troubles had only begun. The water was stored under the tropic sun, the inevitable algæ appeared, plans were made for chemical treatment, a settling basin was prepared, made of concrete, partly on a new fill, which gave all kinds of trouble by cracking, before water could be kept in it. Pressure digesters were put in, gaging and storage tanks for alum were built, pressure filters of a modern type were connected up, Venturi meters provided, and the quality of the water improved. The watershed had already been surveyed and practically all the inhabitants removed. The water unfiltered was safe, and the bacterial content very low, only the algal growths were troublesome. The filters removed them very satisfactorily, delivering 50 to 67 million gallons monthly of clear sparkling water, in all respects as good as many of our best city water supplies in the North.

The filters developed an unexpected phenomenon in that the material evidently segregated; two of the four reduced the bacteria some 75% or more, the other two in some cases increased the bacterial count (560 raw to 18 000 filtered). The colon bacillus did not appear.

It has already been stated that the main pipe line was built

under difficulties; the same was true of the distributing pipe system; the material was not wholly suitable; the writer has counted eight or ten lead joints between a hydrant and its Tee on the street main; it was, therefore, not a surprise to him, on seeing the station Venturi graphs, to note that the night flow (after midnight) was more than 50 per cent. of the usual day flow.

About June of 1906, Congress decided to build a lock canal with locks at Gatun. Surveys were pushed, a town laid out in an upland pasture, tents were pitched to shelter the town builders, and measures taken to secure water for temporary use. Boilers and pumps were installed on the Gatun River a mile away, pipe lines laid, some of the rain-storage tanks formerly used at Cristobal were set upon a high trestle on a hill, altogether some 160 ft. above the pumps, and the town was rapidly built. The writer was, with the construction division officers, transferred to Gatun about March, 1907. The mud was knee deep, two deep cuts were being made between the town and the railway, things were crude generally, but the quarters were comfortable, we could get plenty to eat, such as it was, the work was very interesting, and best of all, we had unlimited water. The Gatun River, a stream of considerable magnitude, drained a good sized bit of country; the exact area was not at last accounts known. The watershed was diversified, some open pastures, much jungle, rather more penetrable than in other parts of Central America, and supported a considerable population. Colon bacilli were always present, so our health department had all houses provided with distilled or at least sterilized water (usually distilled) for cooking and drinking. The town supply was excellent for all other purposes. The twofold supply reinforced for boilers by another storage tank proved adequate and was subject to interruption only from pump breakdown, as the tanks were small. The river sometimes rose to the eaves of the pump house. A dike was built around it and an emergency pump was installed on higher ground, to be used if necessary. The writer recalls only one occasion when it was used. To provide storage a tower tank of some 400 000 gal. capacity was ordered (Plate III, Fig. 2). On arrival it was assembled, taking some five months in the process. When complete, the tank would not hold water; even pneumatic rivet guns could not beat the black laborers.

FIG. 1.

WATER STATION, COLON, 1906.

FIG. 2.

TANKS AT GATUN.

A two-inch coat of cement stopped the leaks, and the tank had not failed at last accounts. About 1909 an electric-driven multi-stage turbine pump was installed, as the older pumps were wearing out.

The supply still lacked perfection as the pumps were some 85 ft. below the level of the proposed lake, which it was proposed to start filling about 1910. Surveys were accordingly made and a site selected for a permanent reservoir. Studies and estimates were made, some of them by the writer, at that time in charge of the Gatun drafting force, for several types of dam, concrete, earth, and earth-faced rock fill. The latter proved most economical as rock and earth were available from the lock excavation less than two miles away. A nearby saddle provided an excellent location for an 80-ft. concrete waste weir. A concrete gate chamber was built, on a pile foundation, also a concrete core or cut-off wall some 100 ft. long; the reservoir site was cleared, the watershed depopulated, a trestle built, and work was started on the dam. Barring sundry freshets, the dam was built without encountering many of the difficulties contended with during the early days of the Colon supply.

A pumping station was designed, with two multi-stage turbine pumps, motor-driven from the main power station a mile or so away, switches were provided to automatically stop and start motors according to stage of water in the storage tank, and Venturi meters, valves, etc., to control the plant. It went into commission in May, 1910.

Analysis of the water (Quebrada las Guacas) indicated that its quality would be a close duplicate of the Colon supply (Quebrada Brazos). The experience there, therefore, was available, and trouble from algæ was expected. It was accordingly thought best to provide for filtration. Several studies were made, none of which seemed to be satisfactory. The writer, being about to leave the service, having nearly completed a continuous four-year term, was detailed to study the problem and report on a suitable plant.

The water of Quebrada las Guacas is in composition and alkalinity essentially similar to that of Brazos Brook, used for Colon's supply. The experience gained at Mount Hope filters thereby becomes available for guidance.

It has been found that these waters can most readily be filtered after the bulk of the organic matter has been removed by coagulation with alum. The operations at Mount Hope had not then been extended over sufficient time to afford a reliable indication as to whether or not lime would be necessary. The plans, however, provided sufficient room for an elevated lime-water tank over the alum tanks if it should prove necessary.

The design is believed to be sufficiently elastic to allow the use of other coagulants in case experience indicates their desirability.

In the use of alum as a coagulant, experience has shown that thorough and immediate mixing of coagulant with the raw water is essential to success. The vortex method, while not so well precedented, promised to be effective and call for much less loss of head than the more usual succession of weirs. It was, therefore, chosen as best adapted to the operating conditions.

The water from the reservoir is admitted through a 16-in. gate operated by a float-controlled hydraulic cylinder. The float valve has an adjustment on the float stem to provide for varying the output of the plant, and on the valve lever to vary the sensitiveness of the valve. An air check valve in the pressure line was provided to allow the gate to close by gravity if for any reason the pressure should fail. In case the consumption increases to such an extent that the float does not operate properly, it can be removed to a special float chamber suitably connected by piping with the mixing tank.

The pipe line from the reservoir to and through the regulating valve was made up of standard fittings, the only special being the nozzle through which the water is delivered to the mixing tank.

This pipe line is provided with a by-pass through which, in case of emergency, raw water can be delivered to the pumps direct; also a pressure line through which the water near the bottom of the reservoir can be pumped to the filters in case it is ever found necessary to consume this lower portion of the water storage.

The coagulant is intended to be dissolved in pressure digesters in the chemical storage room in much the same manner as practiced elsewhere, the solution delivered by the force main pressure into the solution tanks, each of which is intended to hold one day's supply. From the storage tanks the solution is delivered through

float-controlled valves to one of two orifice tanks. These valves can be connected to deliver from either storage tank to either orifice tank, or, if preferred, to the adjacent one only.

The orifice tanks are provided with plate glass fronts. It is intended that this glass shall have a graduated scale and a series of orifices $\frac{1}{2}$-in. and $\frac{1}{4}$-in. diameter. The float valves having adjustable stems, it is possible to vary the head on the orifices and also the number of orifices, thus allowing a large variation in the amount of discharge to accommodate variations in the quality of raw water, the actual discharge to be determined by careful calibration. From the orifices the solution falls into brass or copper funnels connected by pipes of brass or copper with a perforated distributor in the raw water nozzle.

The raw water with its dose of coagulant is admitted to the circular mixing tank in a tangential direction, and after making the circuit of the tank several times is drawn off at the bottom through a 16-in. inverted siphon to a channel, from which it flows in a thin sheet over a weir to the sedimentation basins. The inverted siphon is provided with a drain by which all the water in the coagulant house can be removed when necessary for inspection or cleaning.

The sedimentation basins are designed of sufficient size to allow about one hour or more for the separation of the sludge or precipitate of aluminum hydrate, with most of the grosser impurities, and its subsidence to a point well below the surface.

A submerged weir is provided at mid-length of the sediment basin by which it is expected that the waste of water caused by drawing off the sludge may be materially reduced. Experience indicates that most of the sludge will be deposited in the first basin and can be drawn therefrom at more frequent intervals than from the second basin. The basins are further divided by a drain gallery allowing the basins to operate at half capacity when, if necessary, one section is drained for more thorough cleaning.

It is expected that the ordinary cleaning will be accomplished by drawing off the lower layer of water and sludge, closing the valves when clear water appears at them.

The basins are provided with multi-hopper bottoms, from the apices of which drains lead to a series of controlling valves in the

drain gallery. This gallery is also intended to afford drainage to the filters and to the coagulant and mixing tank and to discharge through a 24-in. circular drain to the brook.

In case experience shall indicate its necessity, provision is made for a system of perforated pipes on the ridges of the hopper bottom through which water under pressure can be discharged in order to wash the sludge from the slopes of the hoppers.

The walls of the drain gallery are to be finished one-half foot lower than the outer walls, to provide, besides economy, a safeguard against the plant overflowing and washing out its foundations, an important item with black attendants. In case the regulating valve should fail to close, the water will run to waste from the sedimentation basin over the wall to the drain gallery.

A grill floor is intended to rest on the ledges and allows access to the valves just below. It is intended that these valves should be of the sluice gate, lever-operated type.

From the sediment basins the water is skimmed by a weir and delivered through a 16-in. pipe and 10-in. valves to the individual filters. From each filter the water is collected in perforated pipes and discharged through an automatic regulator and a 16-in. effluent pipe to a clear water well or reservoir. The filters are 17 by $16\frac{1}{2}$ ft. and are intended to discharge 500 000 gal. each per day, at a rate of about 80 million gallons per acre per day.

It was proposed to import the sand.

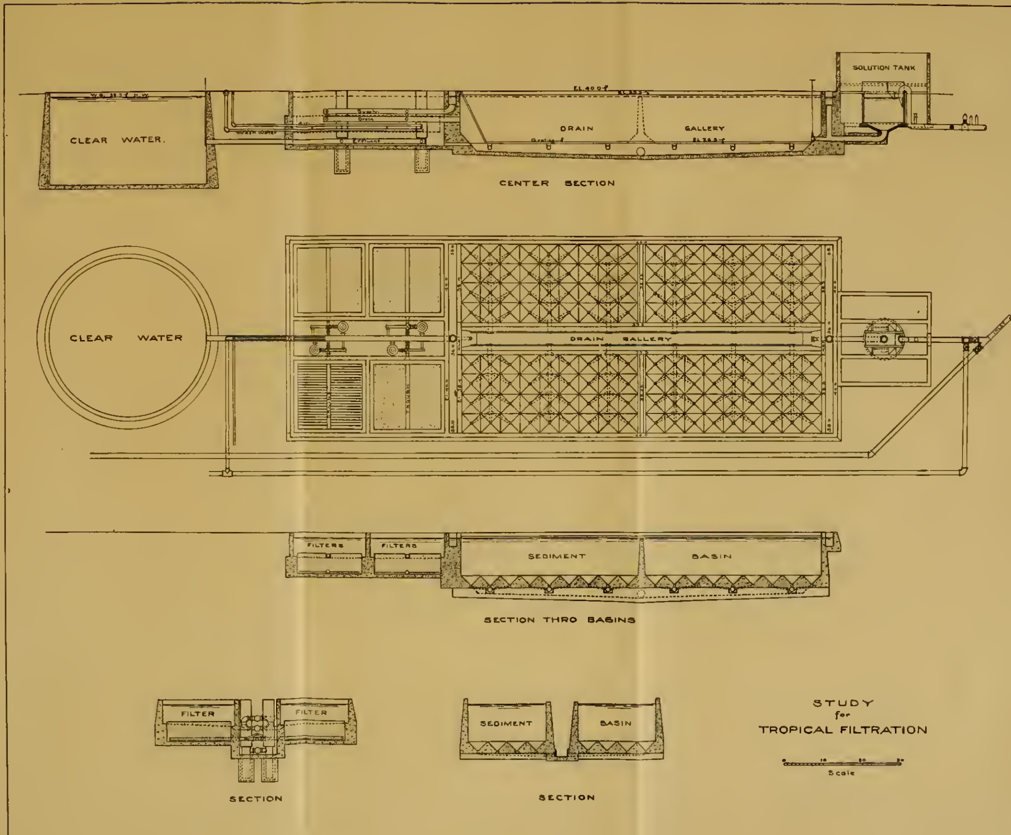
Provision is made for a 10-in. wash water line, taking water from the force main or pump, a 6-in. air line and a 16-in. drain line discharging into the drain gallery of the sedimentation basins. The filter pipe gallery is also drained to the sediment basin drain gallery as shown.

A covered operating gallery may, if desired, be built over the filter pipe gallery. This will allow the valves to be locked up and protected.

The clear water well is made circular in plan to attain maximum economy.

In regular operation it is expected that from one to three grains per gallon of alum will be used. The coagulant basins will be cleaned at intervals of twelve to forty-eight hours, as may prove necessary. The filters will be cleaned at shorter intervals as often

Plate IV.
N. E. W. W. Association,
December, 1911.
Higgins on
Filtration at Panama.



as the operating head reaches about nine feet. An indicator on each regulator float will show this head at all times for each filter, and an electric bell alarm can easily be provided.

Such fancy devices as marble operating tables and hydraulic valves have not been shown, as they are not at all necessary for a plant of this size under Isthmian wage rates.

The material for the filters, tanks, basins, etc., is in most cases reinforced concrete of the simplest possible design, to reduce as much as may be the cost of false work and forms required. The reinforcement has been liberally used, and the plant has been made substantial, to insure as low maintenance charges as possible.

The piping is intended to be cast iron rather than wrought, as the former will be less affected by the chemicals used; valves to be cast iron, bronze faced and lined, bronze stems; floor stands and hand wheels are provided for the filter valves.

Provision was made for considerable future enlargement of this plant if the demand for water should increase to a marked extent. Space was provided, between filters and the clear well, for an additional pair of filters, and the piping was designed to allow their installation with a minimum of expense.

The plan appended (Plate IV) is intended to show the features incident to the foregoing; it is not an exact copy of the plans prepared for the Gatun plant.

DISCUSSION.

Mr. Robert S. Weston. I have been very much interested in this paper because it brings up a problem in water purification which has been quite prominent for some time and is coming into greater notice. We all listened with a great deal of interest to Mr. Wasteneys' excellent paper [1] at Gloucester last September, in which he described experiments on the feasibility of purifying a water of this same class at Brisbane, Australia. It seems that many tropical waters carry a great deal of gelatinous, organic suspended matter which is so fine that it is almost in solution. Under certain conditions this organic matter settles out very rapidly. Of course it can be coagulated out; it can be loaded with

*Journal N. E. W. W. A., Vol. XXV, p. 422.

alum and lime and precipitated. This has been the method described to you this afternoon. Mr. Wasteneys has worked out a solution of this problem based upon the oxidation of the oxidizable material in the water to such a degree that it will precipitate or be removed from the water by ordinary methods of filtration and without using a coagulant, or with the use of very little coagulant.

The same problem though of lesser degree was presented to Mr. Hazen at Springfield, where the water at the Ludlow Reservoir, which was very highly loaded with organic matter, was purified by intermittent filtration. It has also arisen at Athol, Mass., and at Charleston, S. C. It would seem as a general thing that the more economical way of treating this class of waters would be first to oxidize the dissolved matter; that is, to try to apply methods used for the treatment of sewage, in order to remove the food material which forms the basis for growths of algæ and renders purification by ordinary filtration methods difficult, rather than to depend entirely upon slow sand or mechanical filtration methods so useful in a temperate climate.

The operation of the works at Panama, which have just been described here, has within the last few months been noted in some of the engineering papers, or at least in a paper before some engineers' society. If I remember rightly, quantities of coagulant greatly in excess of the one to three grains per gallon estimated had to be used, because this organic matter was in such a condition that it wasted a large amount of coagulant before the coagulation was effected.

The President. I have enjoyed very much listening to the paper, and I would like to ask the author if intermittent filtration was tried on the isthmus at all, experimentally or otherwise.

Mr. Higgins. It had not been up to the time I left. We did not have space for it at this particular plant, that is, within a reasonable distance.

The President. I have had the feeling that intermittent filtration was more economical and also efficient than any other method for these waters containing heavy loads of organic matter, and also abundant iron. The secret of success at Ludlow as at Brisbane is that the water carries plenty of iron, and iron is a

natural coagulant, just as efficient as an artificial coagulant, if it can be handled so as to make it available. Iron is abundant on the isthmus. About 10 per cent. of the weight of the whole isthmus is metallic iron, and it would certainly seem that the iron in the water could be made to coagulate the organic matter in intermittent filters if it is handled right.

NOTES ON TYPHOID FEVER AT WASHINGTON, D. C.

BY W. T. SEDGWICK.

[*Read November 8, 1911.*]

It occurred to me, gentlemen, that it might interest you to hear a very late word concerning the Washington, D. C., situation, with reference to the water supply there. You will remember that when the filters went into operation in Washington, typhoid fever was not reduced, and that a lot of people said it must be that the filters were worthless, since the typhoid was comparatively high, and it had been expected that it would be materially lowered. At that time various local authorities, some of them of a good deal of weight, frankly expressed the belief that the filters were ineffective, and that typhoid fever in Washington was still coming from the Potomac River. But on careful examination a number of us felt perfectly certain that the filters were all right — I mean unprejudiced outside parties who had had nothing to do with the filters whatever, or with their construction. The engineering journals, you remember, contained many articles dwelling upon the various aspects of the subject, and it was one of the most interesting problems of the day.

The main fact stood out, however, that the bacterial efficiency of the filters was very high. Oftentimes they would run for months with an average bacterial discharge of less than 20 per cubic centimeter, and with large numbers only during the winter, or at times when there was no typhoid fever to speak of in the city; so that it proved to be practically impossible to connect in any way a lack of bacterial efficiency in the filters with the typhoid fever prevalent in Washington.

The United States Public Health and Marine-Hospital Service soon went to work (in 1906) on the matter of typhoid fever in Washington, and some of the investigators, at any rate, were at first disposed to blame the typhoid upon the filters, so that there is no question but what they made a most thorough and in one sense

unprejudiced study of the situation. And they have published for every year from 1906 to 1909 valuable reports on typhoid fever in Washington. It so happens that I have to-day the advance sheets of what is likely, I suppose, to be the final report, namely, that for 1909, certainly the latest one up to the present time, which has been made by experienced persons, chief among whom is Dr. Lumsden. I have been going over it rather carefully this morning and with great satisfaction, and I think any of you water-works men would share my satisfaction. For these able investigators, who have now become exceedingly expert in typhoid fever investigations, as a result of their long labors, say that there is no good evidence (and in my opinion there never has been any satisfactory evidence) that the typhoid fever in Washington ever proceeded from any inefficiency or imperfections in the filters.

Of course that raises the question, What then is the typhoid in Washington due to? — and they trace it to various factors within the city, — the peculiar diverse population, largely composed, as it is, of negroes; the extraordinary opportunity offered by the peculiarities of Washington life for contact infection, which is only another name for the spread of disease by contagion; to milk, which is here charged, as everywhere to-day, with some of the principal burdens of typhoid fever transmission; and in this particular report more than any other, to oyster infection. Washington is, as you know, and Baltimore and Richmond also, are centers of the oyster trade, and the eating of raw oysters in those cities, located as they are very near the shores of Chesapeake Bay, a great natural oyster bed, is everywhere practiced. Very careful investigation has made it seem pretty likely that a good deal, a very considerable percentage, of the typhoid fever in Washington comes from that use of raw oysters.

This is one of the newer things in the last report of these investigators; and, summing it all up, they find that there is a great variety of things responsible for the comparatively high typhoid fever in Washington. What you and I are particularly interested in, however, is the fact that at last the water filters are, in the opinion of everybody, I think, who is competent and who has looked into the subject to any extent, relieved of any serious burden in the causation of typhoid fever in that city.

PROCEEDINGS.

November Meeting.

Hotel Brunswick,
Boston, Mass., November 8, 1911.

Mr. Allen Hazen, President, in the chair.

The following members and guests were present:

Honorary Member.

William T. Sedgwick.

Members.

S. A. Agnew, Randolph Bainbridge, M. N. Baker, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, F. A. Barbour, G. W. Batchelder, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, George Bowers, E. C. Brooks, J. C. Chase, R. D. Chase, M. F. Collins, W. R. Conard, J. H. Cook, H. P. Eddy, E. D. Eldridge, F. F. Forbes, A. N. French, A. S. Glover, Clarence Goldsmith, J. M. Goodell, R. A. Hale, R. K. Hale, F. E. Hall, J. O. Hall, W. E. Hannon, Allen Hazen, M. F. Hicks, H. K. Higgins, H. G. Holden, J. L. Howard, A. W. Jepson, E. W. Kent, Willard Kent, F. C. Kimball, G. A. Kimball, A. C. King, J. J. Kirkpatrick, H. O. Lacount, H. P. Letton, N. A. McMillen, A. E. Martin, F. E. Merrill, William Naylor, E. B. Phelps, L. C. Robinson, P. R. Sanders, C. W. Sherman, G. A. Stacy, E. L. Stone, W. F. Sullivan, H. L. Thomas, R. J. Thomas, C. T. Treadway, W. H. Vaughn, R. S. Weston, F. B. Wilkins, F. I. Winslow, G. E. Winslow. — 62.

Associates.

The Anderson Coupling Company, by W. D. Cashin and C. E. Childs; Ashton Valve Company, by C. W. Houghton; Harold L. Bond Company, by Harold L. Bond; Builders Iron Foundry, by A. L. Coulters; Darling Pump and Manufacturing Company (Limited), by H. H. Davis; Hersey Manufacturing Company, by A. S. Glover, W. A. Hersey, and J. A. Tilden; Lead Lined Iron Pipe Company, by T. W. Dwyer; Charles Millar & Son Company, by C. F. Glavin; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by Charles H. Baldwin, H. L. Weston, and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Platt Iron Works Company, by F. H. Hayes; Rensselaer Valve Company, by C. L. Brown; Thomson Meter Company, by E. M. Shedd; Union Meter Company, by F. E. Hall; United States Cast Iron Pipe and Foundry Company, by D. B. Stokes; Henry R. Worthington, by Samuel Harrison. — 21.

Guests.

D. B. Smith, Portland, Me.; W. H. McCann, Lewiston, Me.; J. G. Hill, Lowell, Mass.; R. H. Hunt, Worcester, Mass.; E. B. Carvey, Lowell, Mass.; William Fieldman, E. H. Smith, R. E. Hall, Boston, Mass. — 8.

The Secretary read applications for membership, duly approved, of James A. Cushman, Clinton, Mass., engaged in construction and maintenance of Wachusett reservoir, dam, and aqueduct; John Ware, Downey, Ida., formerly division engineer, Baltimore & Ohio Railroad, later connected with the Boston Elevated Railway Company, and now with Downey Water Company.

On motion of Mr. Bancroft, the Secretary was directed to cast one ballot in favor of the applicants, and, he having done so, they were declared duly elected.

The Secretary read the following communication:

Billerica Water Works.
Office of Water Commissioners.
North Billerica, Mass., November 7, 1911.

New England Water Works Association, Boston:

Gentlemen, — It is the custom with us when application is made for service to have it signed by the owner of the property. In many instances it has come about that the owner has died and his property has passed into the hands of the estate. We would like to get some information as to whether or not it is the usual custom to secure new signed applications from those who take charge of the estate, and would ask you if you would have this come before your meeting. Any information you might be willing to offer us would be gratefully received.

Yours very truly,
(Signed) BILLERICA WATER COMMISSIONERS.
C. W. Mortenson, *Clerk.*

The President. Can some of our members answer this inquiry, as to what their practice is?

Mr. Samuel A. Agnew. That question has come up with us at Scituate a number of times, and I have often wondered what to do about it. We have never yet required a new owner to sign another application, as we call it, but I have expected to have difficulty just on that very score. I am glad this matter has been brought up.

Mr. Robert J. Thomas. We do not require any new application in Lowell, and we have never had any trouble.

Mr. M. F. Collins. It is the same way in Lawrence, Mr. President.

Mr. Richard D. Chase. In New Bedford an application for a service is signed by the owner and reads that it shall continue until revoked in writing. If the property passes to an estate this signature would still hold. If the premises are sold and the first application is not revoked, the bills are sent to the former owner and naturally he settles with the new owner. It is unfortunately true that in Massachusetts water rates are not a lien upon property, but in practice by exercising the right to shut off the water it never fails that some one comes in and settles for back dues. This is really the one sure means of getting bills paid.

Mr. John O. Hall. I think in some cases it is the practice to put upon the form of application a printed statement that the charge becomes a lien upon the estate; then when an application is signed at the office it binds the estate.

Mr. Agnew. That might apply to municipally owned plants, but would it apply to a private corporation?

Mr. Hall. The agreement would be the same if it is a private corporation, and the blank was signed; it would be in the form of a contract.

Mr. George A. King. We don't require any new application in Taunton. I would like to inquire what the use is of having any application in writing from anybody.

Mr. Patrick Kieran (*by letter*). In Fall River we do not require a new application when a piece of property passes to an estate. We do require an application when property is transferred from one person to another.

The first paper of the afternoon was entitled, "Has the Time Come for Double Municipal Water Supplies; One Naturally Pure for Drinking and Cooking, the Other, Denaturized or Sterilized, for All Other Purposes?" by Prof. W. T. Sedgwick and H. P. Letton, C.E., Massachusetts Institute of Technology, and was read by Mr. Letton. The paper was discussed by the President, Mr. Charles W. Sherman, Mr. Arthur N. French, Prof. E. B. Phelps, Mr. Randolph Bainbridge, Mr. Frank C. Kimball, Mr.

John H. Cook, Mr. George A. Caldwell, Mr. John C. Chase, and Professor Sedgwick.

Mr. H. K. Higgins, consulting engineer, Boston, Mass., read a paper in which he gave an account of the development of the water supply and the installation of the filtration plant at Panama. The President and Mr. Robert S. Weston spoke particularly with reference to the problem of filtration.

Professor Sedgwick made a statement concerning the latest results of the investigation as to the efficiency of the water filters and the causes of typhoid fever in Washington, D. C.

The President announced that next month the Executive Committee were planning for a "red-hot" meeting, the subject of which would be "The Material for Service Pipes; whether Wrought Iron or Steel, and How to Treat It." He said that it was expected representatives of various manufacturers would be present to tell what they knew of the methods of manufacture and the merits of the different kinds of pipe, and requested a large attendance of the members.

Adjourned.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Wednesday, November 8, 1911.

Present: President Allen Hazen and members Michael F. Collins, John J. Kirkpatrick, Lewis M. Bancroft, Richard K. Hale, Robert J. Thomas, and Willard Kent.

Two applications for membership were received and recommended for admission, namely:

John Ware, assistant treasurer Downey Water Company, Downey, Ida., and James A. Cushman, engineer of construction and maintenance on Wachusett reservoir, dam and aqueduct, Clinton, Mass.

It was *voted*: That the December meeting of the Association be devoted to the discussion of "Steel *v.* Iron Service Pipes, Galvanizing, and Other Methods of Protection."

Adjourned.

WILLARD KENT, *Secretary.*

BOOK REVIEW.

Home Water Works. A Manual of Water Supply in Country Houses. By Carleton J. Lynde, Professor of Physics in MacDonald College, Quebec. 5 x $7\frac{1}{2}$ inches, xii + 270 pages. 106 text figures. New York: Sturgis & Walton Co. Cloth, 75c. net.

This little book is one of "The Young Farmer's Practical Library," and in it the author presents in simple language a general description of the requirements of a water supply suitable for the country home or farm.

The author gives a brief description, including the materials needed and the cost, of various designs, and shows how such systems may be installed at very slight expense.

The sources of water are then discussed, with a general description of springs and different kinds of wells, the proper methods of construction and the equipment required.

By far the largest part of the book, however, is devoted to a discussion of the elementary physics of pumping and a description of different types of pumps, windmills, tower tanks and pneumatic systems, and the general methods employed in connecting up pumps and engines.

There is also a short chapter on water power, giving a brief description of different kinds of wheels and the methods of connecting them.

In the last chapter the author considers in rather a brief way the problems of plumbing and sewage disposal. The book closes with a list of firms dealing in water supply and plumbing materials.

This is a very good book to recommend to people being out of reach of municipal supplies, for it shows that satisfactory systems can be installed, at very slight expense, which will give much better service than the old-fashioned well from which the water has to be carried to the house.

MEMBERSHIP.

ADDITIONS.

(November 1 to December 25, 1911.)

MEMBERS.

Hyde, John L.
City Engineer, Westfield, Mass.

Miller, Walter E.
Care of Railroad Commission of Wisconsin, Madison, Wis.

Ross, Charles H.
Superintendent Waterloo Water Company, Waterloo, N. Y.

Young, Alfred A.
Superintendent Jewett City Water Company, Jewett City, Conn.

ASSOCIATE.

Eddy Valve Company
Manufacturers of Valves and Hydrants, Waterford, N. Y.

CHANGES OF ADDRESS.

MEMBERS.

Blake, Edmund M.
Care of State Board of Health, Boston Mass.

Evans, George F.
Superintendent Water Works, Manchester, Mass.

Frost, George H.
President Engineering News Publishing Company, 505 Pearl Street, New York City.

Goldsmith, Clarence
Assistant Engineer, Public Works Department, High Pressure Service, Room 18, Old City Hall, Charlestown, Boston, Mass.

Harrub, C. Nelson
Field Assistant, Division Sewerage and Water Supplies, State Board of Health of New Jersey, 246 Highland Avenue, Trenton, N. J.

McKernan, Joseph N.
P. O. Box 149, Plainville, Conn.

Mattice, Asa M.
157 Fargo Avenue, Buffalo, N. Y.

Parker, Horatio N.
College of Agriculture, University of Illinois, Urbana, Ill.

Potter, Philip A.
Engineer, 30 Church Street, New York City.

Smith, Sidney
76 White Street, East Boston, Mass.